NASA CR-66287

REPORT ON THE DEVELOPMENT OF
THE MANNED ORBITAL RESEARCH LABORATORY (MORL)
SYSTEM UTILIZATION POTENTIAL

Task Area III
MORL Concept Responsiveness Analysis

FACILITY FORM 602

N67-19857	
(ACCESSION NUMBER)	(THRU)
308	D
(PAGES)	(CODE)
CR-66287	31
(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

BOOK 2

SM-48814
NOVEMBER 1965

PREPARED BY D. E. CHARHUT
PROJECT MANAGER

APPROVED C E Starns
C. E. STARNS
PROGRAM MANAGER

SUBMITTED BY
DOUGLAS AIRCRAFT COMPANY, INC.

PRESENTED TO
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LANGLEY RESEARCH CENTER
CONTRACT NO. NAS1-3612

APPROVED BY R J Gunkel
R. J. GUNKEL
DIRECTOR, ADVANCED MANNED SPACECRAFT SYSTEMS

(ACCESSION NUMBER) (THRU)
308
(PAGES) (CODE)
NASA-75443
(NASA CR OR TMX OR AD NUMBER) (CATEGORY)
FACILITY FORM 602

DOUGLAS MISSILE & SPACE SYSTEMS DIVISION

KQ743148

The Manned Orbital Research Laboratory (MORL) is a versatile facility for experimental research which provides for:

- Simultaneous development of space flight technology and man's capability to function effectively under the combined stresses of the space environment for long periods of time.
- Intelligent selectivity in the mode of acquisition, collation, and transmission of data for subsequent detailed scientific analyses.
- Continual celestial and terrestrial observations.

Future application potential includes use of the MORL as a basic, independent module, which, in combination with the Saturn Launch Vehicles currently planned for the NASA inventory, is responsive to a broad range of advanced mission requirements.

The laboratory module includes two independently pressurized compartments connected by an airlock. The larger compartment comprises the following functional spaces:

- A Control Deck from which laboratory operations and a major portion of the experiment program will be conducted.
- An Internal Centrifuge in which members of the flight crew will perform re-entry simulation, undergo physical condition testing, and which may be useful for therapy, if required.
- The Flight Crew Quarters, which include sleeping, eating, recreation, hygiene, and liquids laboratory facilities.

The smaller compartment is a Hangar/Test Area which is used for logistics spacecraft maintenance, cargo transfer, experimentation, satellite checkout, and flight crew habitation in a deferred-emergency mode of operation.

The logistics vehicle is composed of the following elements:

- A Logistics Spacecraft which generally corresponds to the geometric envelope of the Apollo Command and Service Modules and which includes an Apollo Spacecraft with launch escape system and a service pack for rendezvous and re-entry maneuver propulsion; and a Multi-Mission Module for either cargo, experiments, laboratory facility modifications, or a spacecraft excursion propulsion system.
- A Saturn IB Launch Vehicle.

Integration of this Logistics System with MORL ensures the flexibility and growth potential required for continued utility of the laboratory during a dynamic experiment program.

In addition to the requirements imposed by the experiment program, system design parameters must reflect operational requirements for each phase of the mission to ensure:

- Functional adequacy of the laboratory.
- Maximum utilization of available facilities.
- Identification of important parameters for consideration in future planning of operations support.

For this reason, a concept of operations was developed simultaneously with development of the MORL system.

PREFACE

This report is submitted by the Douglas Aircraft Company, Inc., to the National Aeronautics and Space Administration's Langley Research Center. It has been prepared under Contract No. NAS1-3612 and describes the analytical and experimental results of a preliminary assessment of the MORL's utilization potential.

Documentation of study results are contained in two types of reports: a final report consisting of a Technical Summary and a 20-page Summary Report, and five Task Area reports, each relating to one of the five major task assignments. The final report will be completed at the end of the study, while the Task Area reports are generated incrementally after each major task assignment is completed.

The five Task Area reports consist of the following: Task Area I, Analysis of Space Related Objectives; Task Area II, Integrated Mission Development Plan; Task Area III, MORL Concept Responsiveness Analysis; Task Area IV, MORL System Improvement Study; and Task Area V, Program Planning and Economic Analysis.

This document contains 1 of 2 parts of the Task Area III report, MORL Concept Responsiveness Analysis. This analysis compares the capability of the baseline MORL concept to the mission requirements as defined in the Task Area II report. Potential solutions for marginal capabilities are also identified and recommendations for further analysis in Task Area IV are made.

The contents and identification of the two parts of this report are as follows: Book 1, Douglas Report SM-48813, presents the results of this assessment; it is supplemented by Book 2, Douglas Report 48814, in which the assessment is based on a detailed examination of a 48-hour segment of on-board operations which are subjected to the same mission requirements.

Requests for further information concerning this report will be welcomed by R. J. Gunkel, Director, Advance Manned Spacecraft Systems, Advance Systems and Technology, Missile & Space Systems Division, Douglas Aircraft Company, Inc.

CONTENTS

FIGURES

TABLES

Section 1
SUMMARY

A segment of the orbital operations that will be conducted on board the Manned Orbital Research Laboratory (MORL) was analyzed, and the results provide a meaningful supplement to the broader responsiveness analysis reported in Book 1 of the Task Area III report. The scope of this analysis was small enough to allow in-depth examination. Therefore, detailed effects of new requirements stemming from mission objectives were identified and compared to the capability of the baseline system to fulfill mission objectives. The resulting degree of accommodation was assessed. Where marginal capabilities or inadequacies of the baseline system were determined, potential solutions were identified.

In general, the capabilities of the baseline laboratory and flight crew to accomplish the operational and experimental tasks selected for analysis were adequate. Shortcomings of the baseline system were identified. To be alleviated, these shortcomings would require modifications to the design; however, these modifications will not result in gross conceptual changes to the MORL.

The composition of the crew did not appreciably vary from the original baseline. The requirement for a medical specialist cannot be justified during the selected operational period (2nd or subsequent year of orbital operations). This position is filled by an experiment specialist skilled in the physical sciences. This modification is logical, since on-board experiments are primarily of an engineering or a scientific nature. Monitoring crew functions and crew performance evaluation will be the responsibility of the experiment specialist who was trained in the life sciences. This specialist is a member of the baseline crew (composition). No unusual or additional skill requirements were identified.

Time-line scheduling was accomplished with minimal deviation from the Phase IIa ground rules for scheduling of crew activities. A high time utilization factor for experiments was attained with only minor gaps of unassigned time remaining. In all, 18 experiments are conducted on board the laboratory during the 48-hour period. This total compares favorably with an estimate of 20 experiments that was based on a Phase IIa statistical analysis.

The limitations of the baseline system that were identified during this analysis are discussed below. Although they stem from the specific experiments chosen for investigation, these requirements are sufficiently representative of the broader experiment program to warrant the required modifications to be accepted as changes to the baseline system. In some cases, the limitations obtained as a result of the analysis supplemented other analyses conducted outside the scope of this study and which indicated that similar remedial action would be required.

1.1 EFFECT OF NEW REQUIREMENTS ON THE BASELINE SYSTEM CONCEPT

The following new requirements have the greatest impact on the baseline system concept:

1. Pointing Accuracy for Experiment Sensors to 0.1° --The mechanical alignment of the current baseline sensing elements, because of their physical locations on the laboratory, cannot be maintained to sufficient accuracy to ensure meeting this requirement. As shown in Figure 1-1, the sensors are located at various laboratory stations. These sensors must be mechanically integrated by mounting them on a rigid structure; that is, an attitude reference base, such as shown in Figure 1-2. The base should also make provisions for accommodating the various experiment sensors which depend on a precise alignment link to the attitude reference system.

2. Requirement to Handle High-Rate and Video Data--The baseline communications and telemetry subsystem cannot accommodate the high-rate or video data generated by the experiments selected for this analysis. The problem has been approached by considering that the equipment providing this capability is part of the experiment equipment; for example, the wide-band recorders which store radar and IR data are part of the experiment equipment. This approach avoids the real problem of system design. In reality, the baseline

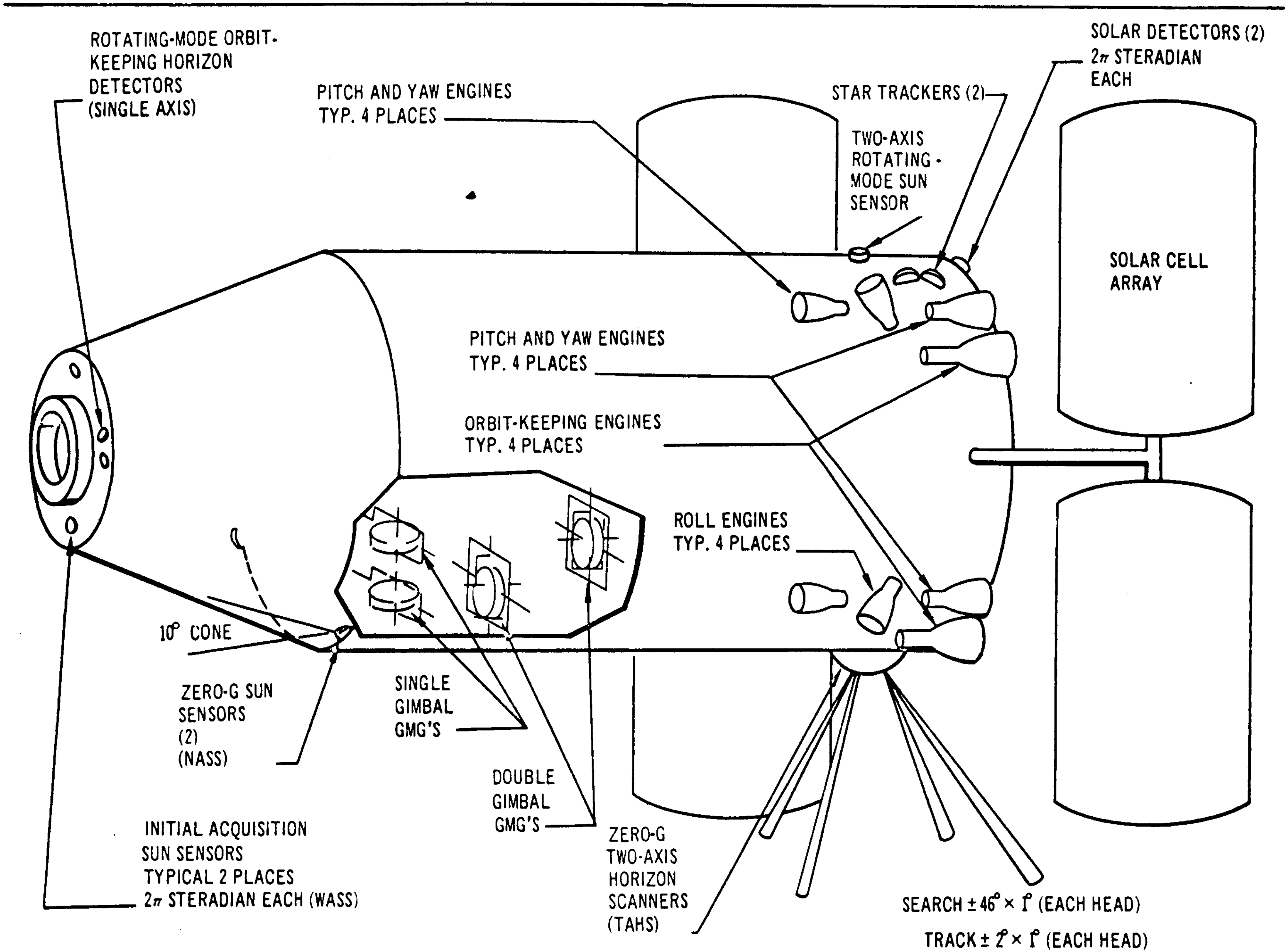


Figure 1-1. Sensor and Actuator Locations – Baseline System

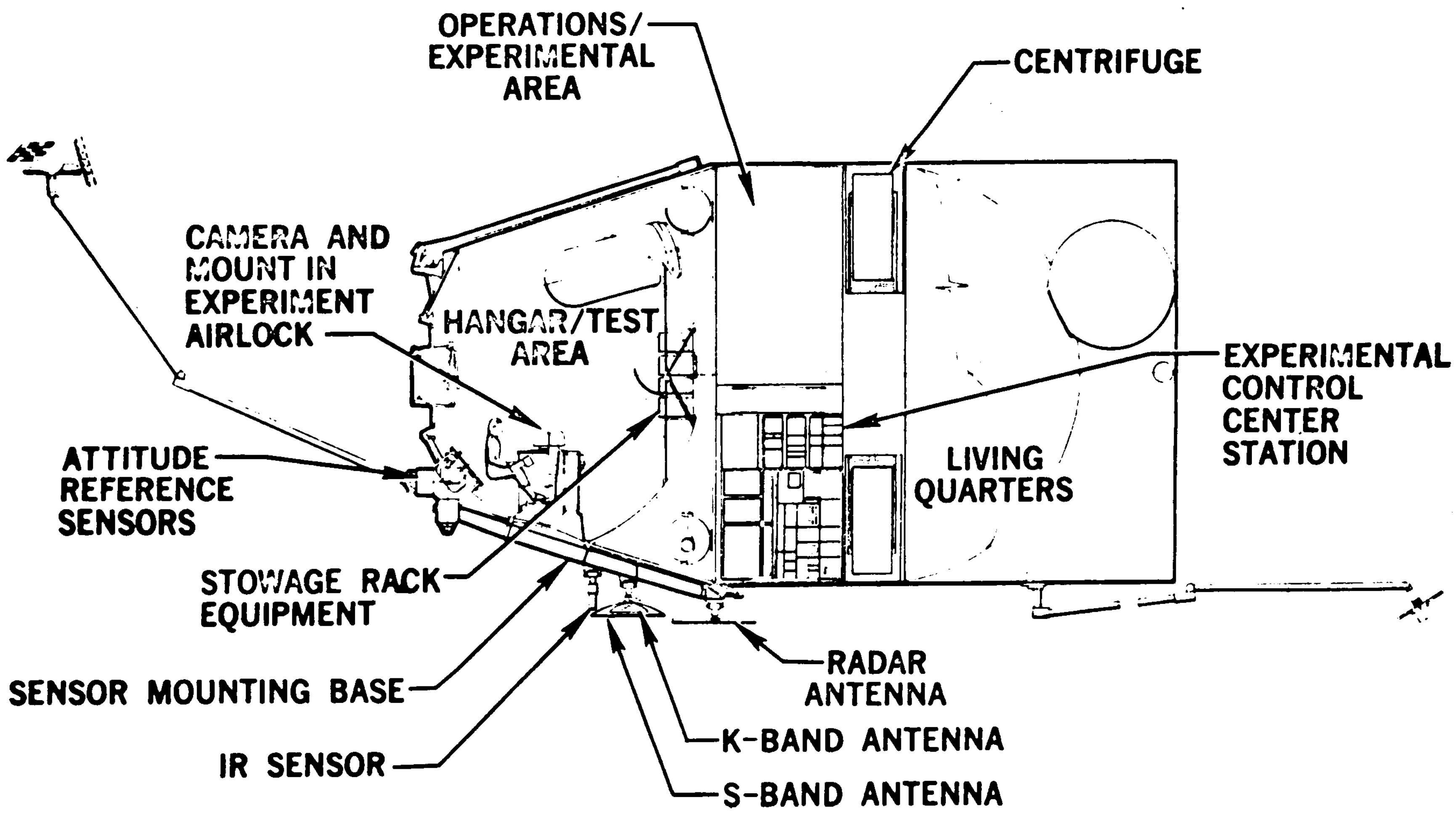


Figure 1-2. MORL Inboard Profile – 48 Hr Study

system should be reconfigured to provide a wide-band data handling capability. Also, it is implicitly evident that many of the requirements which are satisfied are met in a nonoptimum manner. For example, data are sampled at higher rates simply because only fixed discrete sampling rates are available, or cross-strapping of a number of channels is required to obtain a higher sampling rate not normally provided. A multiplexer that can be programmed and can be controlled manually and automatically is required to provide optimized data-sampling formats.

3. Additional Experimental Control Provisions in the Hangar/Test Area--The experimental airlock will be used many times during the 48-hour period. Some experimental equipment operating in the airlock cannot be remotely controlled from the experimental console located in the Operations/Experimental Area. Therefore, a new console and operator control panel should be provided near the airlock.

4. Marginal Contact Time in 50° Inclination Orbit--The required 45-min. telemetry dump time per day is only marginally met in the 50° inclination orbit with the baseline network of TEX and KEN. In addition, tracking capability is provided only during three, rather than four, successive orbits. This indicates the necessity for expanding the baseline network.

5. Command Data and Tracking Coverage During Experiment Runs--The required transmission of command data (primarily start-stop times or sensor-pointing angles), prior to a run over an instrumented ocean range and subsequent tracking during the run, cannot be accomplished with the baseline network, even with a reasonable extension of the network. This can be solved by limiting the number and the location of the runs to areas adequately covered by the network.

6. Crew Skill Requirements--The composition of the baseline crew is changed to include a second experiment specialist trained in the physical sciences, rather than an experiment specialist trained in medicine. This change is necessitated by the reduction in biomedical testing and the increase in engineering/scientific testing.

1.2 PERTURBATION ANALYSES

Six perturbations to the planned on-board operations have been examined to determine their effect on the experiment program, the laboratory, and the flight crew. The following conclusions were reached:

1. Perturbations such as those examined would disrupt the predetermined schedule of on-board activities and, particularly, the experimental program.

2. Return to the schedule would be accomplished within a day's time because of the unassigned time (approximately 18 hours/day) made available to accommodate such perturbations.

3. The flight commander is involved in every major perturbation; therefore, his schedule should have a minimum of assignments, especially experimental, and a maximum of unassigned time.

4. The unavailability of spares for repair was not judged critical to the survival of the laboratory or the flight crew; however, in at least one instance, the unavailability of spares may have a major effect on the experiment program.

1.3 RECOMMENDATIONS FOR FOLLOW-ON ANALYSES

Because of the new requirements identified during this analysis, and because of the corresponding limitations or marginal capabilities inherent in the baseline system, recommendations for continued investigation are contained in the following sections.

1.3.1 For Task IV Analysis

Recommendations for continued investigation in Task IV Analysis are as follows:

1. Investigate the feasibility of mechanical integration of attitude reference and experiment sensors by mounting them on a rigid structure (reference base).

2. The amount of extravehicular activity required to install and replace experiment sensors, exchange experimental specimens for tests of relatively long duration, and the lack of capability to easily perform extravehicular operations such as calibration of sensors, indicates the desirability of performing such activities in a shirt-sleeve environment. This may be accomplished by providing a separate bay containing a rigid beam on which experiments with external sensors may be mounted along with the attitude reference sensors. The area could be enclosed to permit pressurization and control suitable for a shirt-sleeve environment. Installation, checkout, calibration, repair, and replacement then could be easily performed. Doors or some other suitable cover could be then opened to permit the sensors to see the intended target. It is recommended that such a concept be investigated for possible incorporation into the baseline MORL design.

3. Investigate the feasibility of incorporating a new console and operator control panel in the Hangar/Test Area located near the experimental airlock.

4. Consider the addition of another ground station to the baseline network (TEX and KEN) to increase contact time and improve marginal capabilities for the 50° inclination mission.

5. Review spare provisioning plans for C-band transponder components. These spares should be given high priority, especially when the MORL is engaged in Earth-centered experimentation.

6. Some other problem areas of lesser importance identified during the 48-hour analysis and where additional investigation may be warranted are as follows:

   A. Selection of a normal egress route from the laboratory for extravehicular operations and the establishment of procedures.

   B. Determination of the placement of space suits. Is there a requirement for an extra suit for each crewman, for example, located at each exit?

   C. Packaging of experimental equipment, especially the equipment for the experiment console, should be such that the components are already integrated in a package that can easily be integrated into the console.

   D. The experiment console should have a universal electrical harness, provisions for plugs, racks for equipment, and provisions for easy installation and removal.

1.3.2 For Follow-On Studies

Recommendations for follow-on studies are as follows:

1. In relation to Item 1 of Section 1.1 regarding compliance with the pointing-accuracy requirements, a much broader problem is clearly indicated. This problem begins at the requirements definition stage and proceeds through performance evaluation. The following three-step study is, therefore, recommended:

   A. Experiment-Control Interface--During the 48-hour study, the perturbations caused by integrating a few selected experiments were investigated. An expanded version of this study is recommended to further define the requirements imposed by the complete spectrum of experiments and to determine which requirements recur sufficiently to warrant a change in the control-experiment interface or the total vehicle-experiment interface.

   B. Experiment Alignment--The problem area associated with the experiment-control interface should be analyzed in detail to determine means of establishing and maintaining sufficient alignment accuracy between the experiment and the laboratory's attitude reference system. In some cases, experiments must be pointed toward an object with an accuracy of 0.01^{o}, or better, with respect to the on-board reference, which is aligned to the same order of accuracy. This problem, difficult to solve in a ground-based laboratory, is further complicated by the requirement to install the experiment in the orbital environment at a point several feet away from the reference source, and to accomplish the alignment with a minimum expenditure of crew time.

While this problem is being investigated in the current study phase, it is recommended that the study be extended to include a more detailed definition of the alignment scheme. It is also recommended that perturbations resulting from temperature differential, pressure differential, and vibration effects be evaluated, and that error analyses be conducted to determine expected accuracies as a function of the alignment technique and procedure chosen.

C. Experiment Performance Evaluation--After the experiment-control functional interface has been defined and the error contribution caused by misalignment has been determined, the overall performance of the experiment-control system combination should be evaluated. This study would also define several basic types of experiments requiring sensor pointing and tracking with and without information derived from the target objectives.

The experiment control requirements would be defined in terms of the discrete and variable functions to be generated and the data accuracies and resolutions to be measured and processed. Computational requirements for the central data computer and the control data computer would be developed, and the effects of varying the experiment sensor control laws would be examined.

Simulation of the complete system, including computers, sensors, control laws, and error sources, would provide an evaluation of the expected performance of the experiment. On the basis of these results, the adequacy of each major element in the total experiment-control system complex can be evaluated and the need for initiating development activity can be defined.

2. The navigation requirements imposed by the oceanographic experiments indicate that the baseline navigation technique is unsatisfactory. The primary problem is caused by the lack of real time updates in conjunction with the experiments. The addition of tracking sites will not improve this situation. Restriction of the ocean area to be observed appears to be the only solution. This solution, although realistic, adds a severe constraint to the basic capability of an orbiting research laboratory to conduct synoptic measurements. Therefore, an autonomous navigation system is required that permits update fixes to be taken when needed. It is recommended that an examination of this application for MORL be undertaken as a future improvement to the baseline capability.

3. A purposeful redesign of the communications and telemetry subsystem hinges on the definition of a set of valid requirements. This definition must include not only information on the number of data sources and their data rates for each experiment, but also data on the scheduling of the experiments. The availability of this type of information has been limited primarily because these requirements were not defined within the individual experiment descriptions. Therefore, a follow-on study is recommended to gather detailed data requirements representing a realistic experiment plan for MORL. The experiment plan derived in the MORL Phase IIb study

may be such a plan. The scope of this investigation would allow the identification of a sufficient number of valid requirements to adequately configure a communications and telemetry subsystem with the flexibility required for space operations.

4. A second follow-on study is recommended to investigate advanced techniques of data handling for space laboratories. Adaptive data acquisition and compression techniques should be given prime consideration.

5. The addition of the attitude reference and experimental sensors mounted to a common rigid base (see Figure 1-2) adds to the congestion at the forward end of the laboratory. It is recommended that the location of logistics spacecraft stowage, docking and stowage mechanisms, experimental booms, experiment sensors, and the attitude reference base be examined to ensure optimum location on the laboratory.

6. Techniques for automatically or semiautomatically monitoring biomedical subjects should be investigated. Currently, this task requires a significant amount of crew time. The task is also difficult to schedule because one crewman is assigned the task of observing all other crew members at various times each day.

7. Techniques for performing personal hygiene functions should be investigated. The procedures not only are important, but design details may require considerable lead time to complete.

8. The need for restraints, tools, and handling aids in a zero-g environment should be investigated. This would include such diverse situations as restraining food in a zero-g oven, transporting handheld objects from one location to another while using hands to aid in locomotion, restraining experiment equipment and supplies, and performing most housekeeping tasks.

9. The techniques used to generate the 48-hour time-line schedule were time consuming and laborious. However, at least this depth of analysis is required before an actual flight schedule can be established. A great deal of time is required to establish a flight plan for an extended-duration mission for the MORL, although the plan can be formulated in segments. Furthermore, in-orbit adjustments of duty schedules necessitated by unscheduled events will also consume a significant portion of at least one crewman's time; therefore, improved techniques for automatic scheduling of crew functions should be investigated.

Section 2
INTRODUCTION

This report presents the results of a detailed analysis which considers a 48-hour period in the operational lifetime of the MORL. The events which take place on board the laboratory and the corresponding ground support activities are examined to determine the extent to which the baseline MORL system can accommodate the requirements imposed upon it.

Measurement of the responsiveness of the baseline MORL system during the MORL Phase IIb study is accomplished by comparing system and subsystem capabilities to the requirements depicted or inherent in the Integrated Mission Development Plan. These requirements stem from two distinct sources: (1) those operations required to sustain the laboratory in orbit, and (2) the experiments to be performed on board the research facility. Operational requirements are examined for major impact on the various system and subsystem elements of the MORL. These requirements include: those associated with specific orbital characteristics, such as altitude and inclination; the corresponding environment, such as radiation and meteoroid intensities; those requirements imposed by the selection of mission vehicle elements, and, finally, a time-phased schedule for mission operations. Upon translating these general mission requirements into specific system and subsystem requirements, the degree of accommodation of each system element can be obtained, and marginal capabilities or gross inadequacies identified.

Because of the size and scope of the experimental program being considered for the MORL, the determination of specific system and subsystem requirements is not easily accomplished. Many of the experiments are not sufficiently defined to permit a rapid identification of subsystem requirements without further investigative analyses. Therefore, accommodation of experimental requirements is determined in the following manner. Experiments are scheduled into an Experiment Plan in a manner to ensure that the MORL's resources will not be exceeded. In such a complex scheduling program, the number of resources selected as constraints are naturally limited to those having the greatest impact on the sizing of the MORL system. This technique of measuring the MORL's responsiveness is a positive one in that the resulting Experiment Plan is not only, by definition, compatible with MORL's resources, but also in that it indicates the degree of compatibility by identifying the resource utilization attained in such a plan. Optimization of the scheduled plan can then continue to define that plan which will provide the best overall utilization of the laboratory's resources.

In addition to examination of laboratory sizing parameters, experiments in the Data Bank are examined for the purpose of making a gross assessment of subsystem accommodation. These analyses identify those experiments which can be accommodated without changing the baseline design and those which would require modifications. These analyses similarly result in a gross determination of subsystem adequacy to support an extensive experimental program as represented by the Data Bank or those experiments constituting the Experiment Plan.

2.1 PURPOSE

The purpose of the 48-hour analysis is to supplement these system and subsystem sizing analyses with a detailed examination of operational and experimental requirements. Favorable results of such an analysis would enhance the confidence level in the MORL's ability to perform an extensive experimental program as indicated by the Experiment Plan.

To carry such an investigation to the desired depth of analysis, the scope of the analysis has been restricted to a 2-day, representative segment of orbital operations. For this period, every event taking place on board the laboratory is identified and examined. Interfaces between experiments and baseline laboratory equipment are also identified. Detailed crew movements are traced to determine realistic time estimates for the conduction of routine and experimental tasks. Marginal laboratory capabilities and procedures are identified, and recommended solutions for achieving full responsiveness are made. These recommendations are then available, along with those stemming from the broader responsiveness analyses reported in Book 1, for considering changes to the baseline MORL design.

2.2 SCOPE AND ASSUMPTIONS

This study examines a representative 2-day period from the 5- to 10-year lifetime of a MORL. Of the three orbital missions (50°, polar, and synchronous) under investigation during the Phase IIb study, the 50°-inclination 200-nmi-altitude orbital mission was chosen. The study considers all on-board activities during this interval and the corresponding ground support activities required to maintain the MORL in orbit and to provide the necessary support for the experimental program in progress.

During this period all routine operations, that is, all scheduled events having frequency of 2 days or less, are considered. Less frequent activities and unscheduled events are initially omitted to establish a base that is free of major perturbations. Then the effects of some selected perturbations are examined for their effect on these operations. Experiments to be performed are scheduled so as to attain the highest possible utilization of crew time. Barring unanticipated difficulties, the on-board operations can then represent a predetermined flight plan. By use of such a time period, constructed in this manner and representing an optimistic but realistic scope of work attainable on the MORL, an opportunity to measure the MORL's capability to accomplish these tasks, when the demands on its resources are at their highest overall level, will be provided.

2.3 STUDY APPROACH

The approach to this analysis consists of a two-part study. Initially, a 48-hour period highly saturated with crew activities, consisting of routine operations based on the assumptions in Section 2.2, is constructed and analyzed. The accommodation capability of the baseline system is assessed, and limitations and marginal capabilities are identified. Subsequently, other less frequently scheduled operations and some selected unscheduled events are introduced as perturbations to determine the effect on the crew's ability to solve the problem or to accommodate the operation, and to determine the crew's ability to return to a normal experimental program.

The study approach is depicted in Figure 2-1. Formulation of the time-line analysis is accomplished by first preparing activity flow charts for all routine operations and all experiments. These charts illustrate each step of operation required to accomplish these tasks and, once the corresponding time intervals are estimated, a PERT-type network is established on an individual task basis. Where warranted, more detailed task descriptions are prepared to further define the interfaces with equipment and facilities. This information is then scheduled into a detailed time-line analysis. The effect of the experimental program on each MORL system and subsystem is determined by comparing the experiment requirements with the baseline capabilities; deficiencies are noted and potential solutions are identified. No attempt is made at this point to reoptimize the MORL system for these new requirements because they, and the potential solutions, will be considered along with other operational and experimental requirements in the MORL System Improvement Study of Task Area IV.

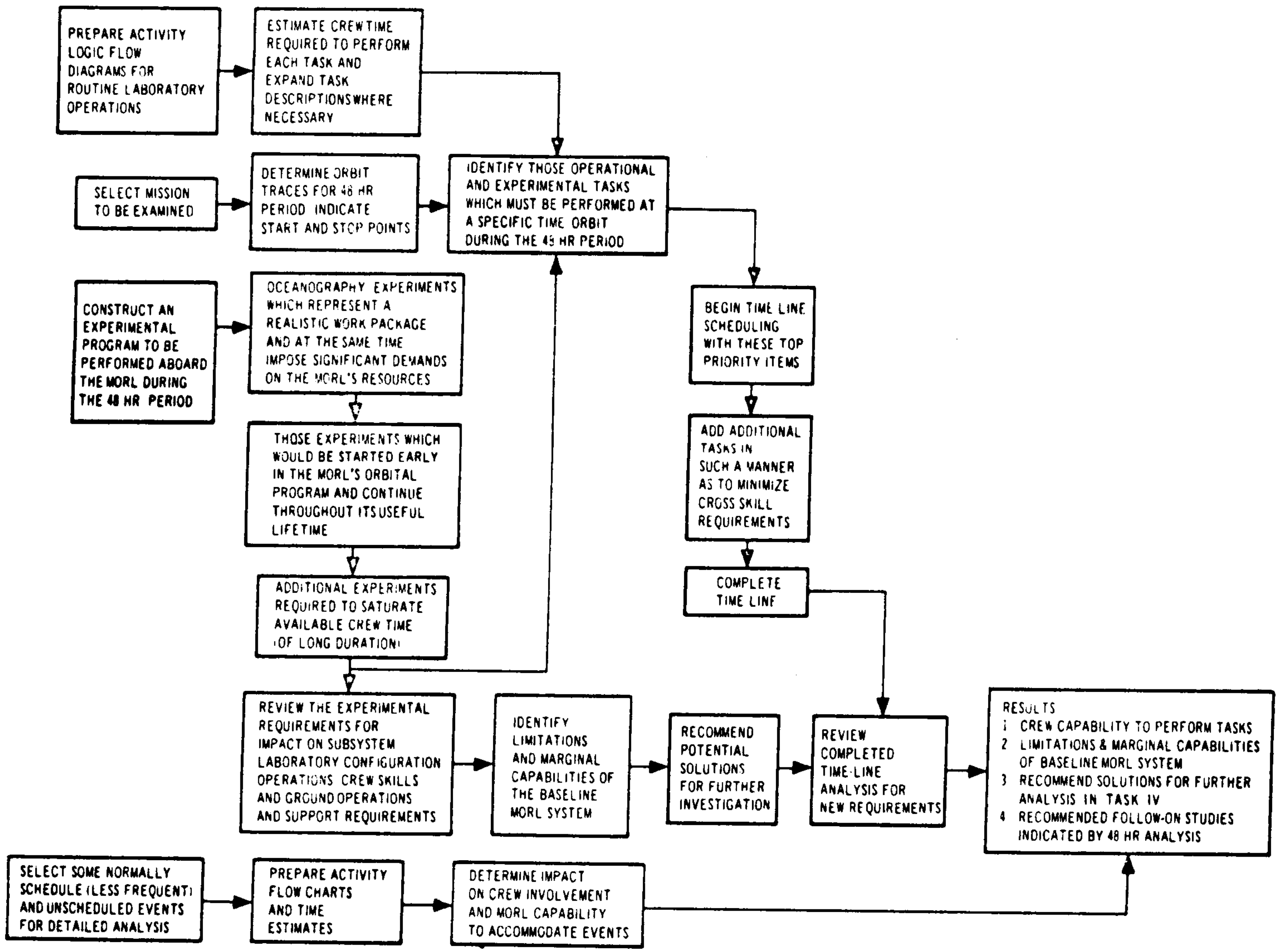


Figure 2-1. Study Plan (48-Hour Study)

Section 3
MISSION DESCRIPTION

The 48-hour segment of time chosen for analysis is assumed to be typical of orbit operations sometime after the 1st year of the MORL mission. The major questions and tests associated with determining the flight crew's performance in a long-duration zero-g environment have been accomplished. The primary mission of the laboratory involves Earth-centered applications, specifically oceanography and meteorology. The state of developing these capabilities is related to the second tier of orbital tasks depicted in the Applications Plan included in the Task Area II report, SM-48810 through 48812. This level of testing involves the performance evaluation of equipment which, in this case, is multispectral sensors. A discussion of these tasks can be found in Section 4.

The laboratory is fully manned with a crew complement of six men. An active experimental program is in progress during the 48 hours of activity chosen for detailed examination.

3.1 ORBIT CHARACTERISTICS

Orbit characteristics of the MORL are as follows:

1. The MORL is in a 200-nmi circular orbit; the orbit is inclined 50° to the equator.
2. The laboratory is in a belly-down orientation during the performance of Earth-centered experiments.
3. After an orbit-keeping maneuver has been completed, no further orbit corrections will be required during the following 48 hours.
4. The orbit traces for the 48 hours are shown in Figures 3-1 and 3-2. They are numbered from the beginning of the selected time period.

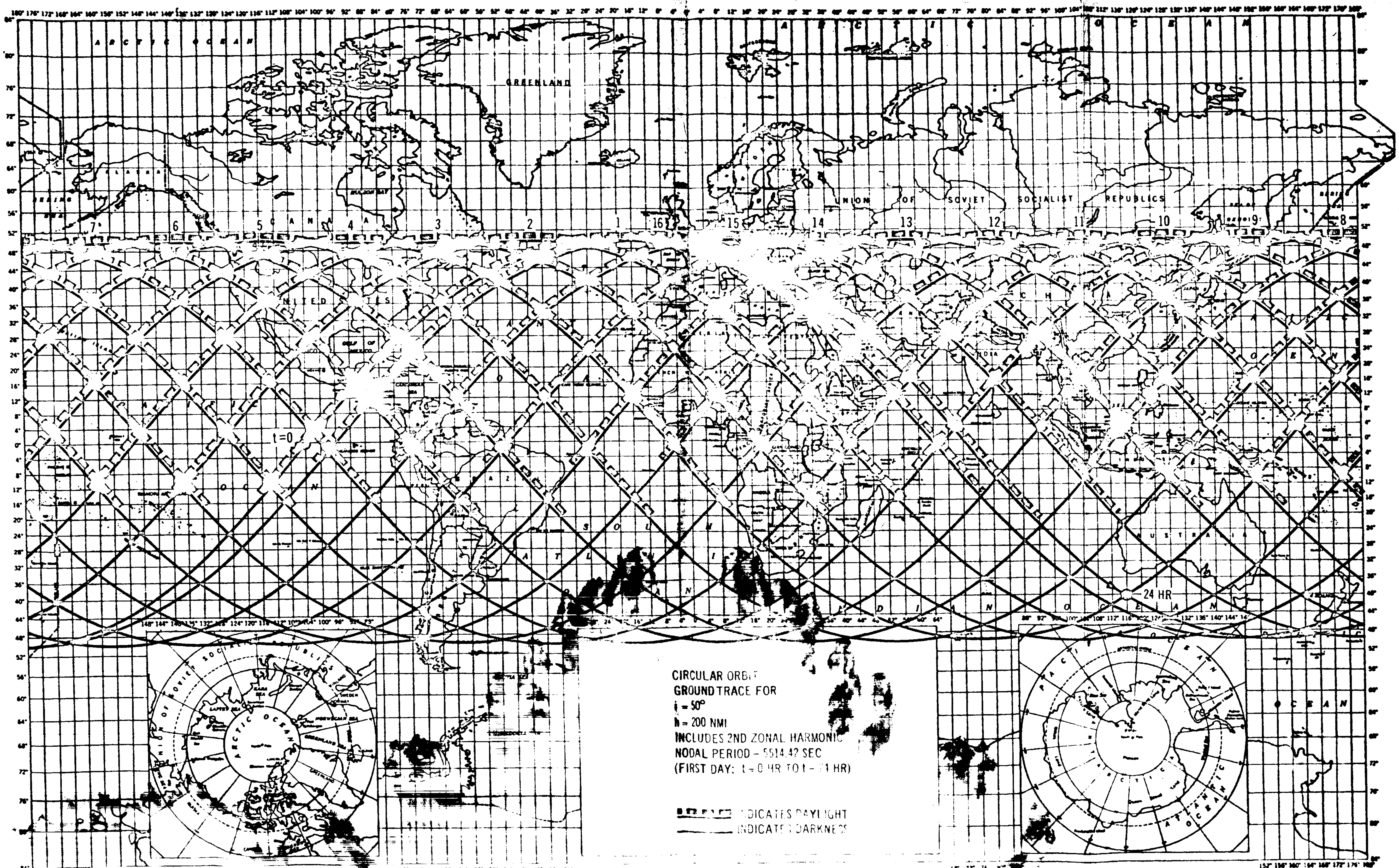


Figure 3-1. Circular Orbit Ground Trace (First day: t = 0 HR TO t = 24 HR)

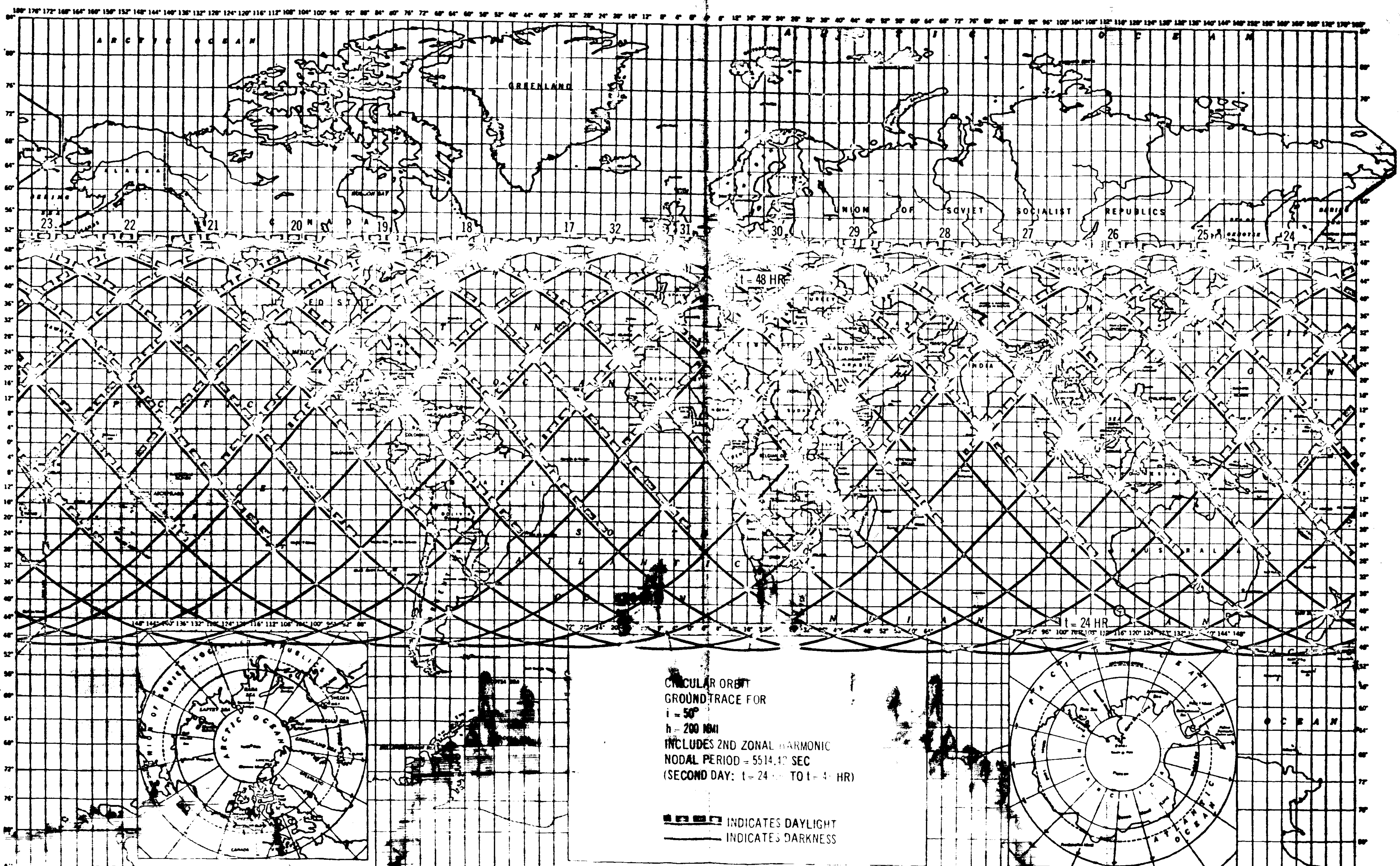


Figure 3-2. Circular Orbit Ground Trace (Second day: t = 24 HR TO t = 48 HR)

3.2 OPERATIONAL TIME PERIOD

Operational time period characteristics are as follows:

1. The beginning of orbit tracer No. 1 (T_0) is assumed to be at 6:00 a.m. local time. Periods of daylight and darkness are indicated in Figures 3-1 and 3-2.
2. Three crewmen come off duty and proceed to the living quarters for rest; the other three crewmen are on duty status.

3.3 LABORATORY CONFIGURATION STATUS

3.3.1 Laboratory

Configuration of the laboratory systems is as follows:

1. Two Apollo spacecrafts and a cargo module are located in stowed positions on the MORL.
2. A logistics spacecraft will not rendezvous nor will a cargo module be jettisoned during the 48-hour period.
3. All laboratory systems, such as EC/LS and RCS, have sufficient quantities of expendables aboard the laboratory.
4. All systems are functioning properly.
5. The articulating booms are empty and stowed.

3.3.2 Experiments

Status of the experiments aboard the spacecraft is as follows:

1. The photography experiment has been set up in the experiment air-lock and is standing by for the initiation of a target run; sensor optical alignment has been accomplished.
2. The microwave experiment equipment has been set up and aligned, and is standing by for a target run.
3. The IR equipment has been set up, and it is turned off; initiation of further IR tests will be accomplished within the 48-hour period.
4. The radar equipment is crated and stowed in the hangar/test area equipment rack. It will have to be removed, set up, and aligned during the 48-hour period.
5. The cosmic dust (IA-1) sensors are located on the four masts. The experiment will require a calibration check sometime during the 48-hour period.
6. The high-energy particle, radiation experiment (IB-23) is in progress; the samples are located on the exposure racks.

7. The measurement of solar absorptivity and thermal emissivity experiment (IIIB-6) is continuous and in progress; the samples are mounted externally. The experiment will require that an exposed sample be brought into the laboratory for analysis and then returned to space for further exposure. Routine maintenance and inspection of the gimbaled exposure rack will have to be performed.

8. The thermal equilibrium experiment (IC-15) is in progress, all thermocouples are placed, and no inspection or maintenance will be necessary; results will have to be recorded.

9. The communications experiment (IIC-1) has been set up for some time; the antenna is in position, and no maintenance or equipment changes will be necessary.

10. The fatigue test of materials experiment (IIIB-3) has been in progress. The machinery for cycling tests is in the stowed position in the hangar. The equipment will have to be set up in the airlock for a test run of 2 hours. The fatigue samples are on the exposure racks; one sample will have to be retrieved from the outside and set up on the test apparatus. Also, the twin sample will have to be retrieved. Both the fractured sample and the twin will have to be packaged for return to Earth.

11. The evaluations of behavioral responses, Parts I and II (IIIA-5 and -6) have been in progress; tests will be performed on each crewman during the 48-hour period.

12. The retention of skills experiment (IIIA-8) has all necessary equipment set up and operating; tests will be performed on the crew.

13. The crew performance experiment (IIIA-7) has been set up and is in operation. Rendezvous and re-entry simulation will be accomplished. No equipment maintenance or checkout will be necessary.

14. The ionizing radiation experiment (IA-11) has been in progress. Twelve hours have elapsed since recharge of the crew dosimeter electrometers; they must be recharged every 24 hours. The film badges are 6 days old; they must be exchanged after 7 days and the film will be processed and developed.

    The internal ionization and scintillation equipment has been installed and is operating; no further action is required.

    The space radiation telescope (SRT) equipment is stowed in the hangar deck. It will have to be installed on the boom (mated to the experiment airlock), extended for a test run, and returned to stowage.

15. The ventilation of respired gases (IIID-17) experiment apparatus has been set up and is operating. A sample of air will have to be tested during the 48-hour period. The gas chromatograph has a sufficient carrier gas supply to last through the 48-hour period.

16. The EC/LS monitoring test (IIID-16) has been in progress. A 1-week supply of growth plates has been used and must be prepared for the next week. Growth samples must be prepared and incubated

for 24 hours. The previous 24-hour sample must be prepared for analysis and analyzed. The process must be repeated every 24 hours of the 48-hour period.

17. The force producing capability experiment (IIIA-4) equipment has been set up. No further apparatus changes are required.

Section 4

EXPERIMENT PROGRAM

Eighteen active experiments are being performed on board the laboratory during the 48-hour period selected for investigation. The experiments are listed in Table 4-1, and are described in the appendix to this report. Selection of the experiments was based on the considerations presented below.

The four oceanographic experiments were chosen because they require the use of the four types of sensors most likely to be tested in space for operational applications of Earth-centered missions. The experiments involve radar, photography, microwave radiometry, and infrared radiometry. Because the areas of oceanography and meteorology, among Earth-centered applications, were the most thoroughly investigated during the Phase IIb study (hence, the most data were available), the selection was straightforward.

Although the duration during which these four experiments remain active encompasses several months, only a 2-day increment was investigated. To expose the flight crew to a wide range of in-orbit operations, these experiments were assumed to be in different stages of operation. For example, while the radiometry equipment was assumed to be completely installed and operating, the radar experiment was not yet assembled in position. Therefore, the entire installation, checkout, calibration, and operation procedures were analyzed in the 48-hour analysis. Similarly, the photography experiment required installation of the camera into the experimental airlock prior to taking data. In this manner, from these four experiments, a broad view of the different aspects of handling an experiment on the MORL could be illustrated.

The selection of these four experiments was greatly influenced by the synoptic data gathering requirements they impose on the laboratory subsystems.

From specific orientation, pointing accuracy and hold requirements, to a wide range of data types to be managed, an excellent cross-section of the demands made on the laboratory was obtained. Furthermore, it is considered quite realistic to assume that a group of experiments such as these could be operating on the MORL simultaneously.

The second group of experiments selected consist of those measurements which begin early in the first MORL mission and continue throughout the lifetime of the laboratory. These are the engineering and scientific experiments which measure the external environment and the effects of the environment on material samples. The Biomedical/Behavioral experiments in this class concern themselves with the continuous assessment of the crew's capability to perform their assigned tasks efficiently. There are four experiments in this category.

The third and last group of experiments are those which do not extend for the lifetime of the MORL but experiments with a duration sufficiently large, about 1 year or so, to ensure that they could easily and realistically be scheduled during this 48-hour time period. Of the 18 active experiments, 10 fall into this category.

The total of 18 active experiments represents a realistic load for the MORL. It also confirms an early estimate made in Phase IIa based on a statistical analysis that, on the average, approximately 20 experiments would be active on board the MORL at any time.

As discussed in Section 5, the available crew time was not completely saturated with task assignments. This is partially because of the unavailability of additional experiments of the types described above which had small daily demands on crew time, yet were to be performed frequently enough to be chosen realistically for inclusion in the 48-hour study period.

Table 4-1

EXPERIMENTS DURING THE 48-HOUR STUDY

	Engineering and Scientific Experiments	Identification No.
1.	Design evaluation and approval tests of final radar equipment	AP-252
2.	Design evaluation and approval tests of variable focal length, high-speed, large format camera	AP-255
3.	Design evaluation tests of microwave radiometers	AP-256
4.	Design evaluation tests of infrared radiometer	AP-257
5.	Cosmic dust measurement	DB-IA-1
6.	Effects of high-energy particulate radiation on selected living and nonliving materials	DB-IB-23
7.	Measurement of solar absorptivity and thermal emissivity	DB-IIIB-6
8.	Space vehicle equilibrium study	DB-IC-15
9.	Evaluation of communication techniques	DB-IIC-1
10.	Fatigue tests of material after exposure to space environment	DB-IIIB-3
11.	Ionizing - radiation measurements	DB-IA-11
12.	Ventilation of respired gases in manned space enclosures	DB-IIID-17
13.	Evaluation of life-support system to detect micro-biological and chemical contaminants	DB-IIID-16

	Biomedical and Behavioral Experiments	Identification No.
1.	Evaluation of behavioral responses in the orbital environment - Part I (standard behavioral measurements)	DB-IIIA-5
2.	Evaluation of behavioral responses in the orbital environment - Part II (Journal Recording)	DB-IIIA-6
3.	Retention of skills learned in the orbital environment	DB-IIIA-8
4.	Crew performance in orbital and re-entry operations	DB-IIIA-7
5.	Force-producing capabilities of operators in zero g	DB-IIIA-4

Section 5

FLIGHT CREW ACTIVITY ANALYSIS

An analysis of flight crew activity required during the 48-hour period was conducted in order to establish crew size and composition requirements and to identify any man-system integration problems which might be apparent at this stage of development. The steps in the analyses were as follows:

1. List mission functions requiring human participation.
2. Define crew tasks required to complete each function.
3. Assign time estimates and skill level to each task.
4. Schedule and assign tasks to individual crewmen.
5. Concurrently, resolve human factors problem areas.

Operational functions were listed first, because they are essential to crew survival. Second, experiment and measurement functions were listed. Functional flow diagrams detailing the procedural tasks involved were then prepared so that realistic time estimates and skill levels could be derived.

Table 5-1 summarizes the time estimates for each flight crew activity and time allocation. For comparative purposes, results of the 48-hour analysis and the original baseline figures are shown. As expected, they are generally comparable. The most notable discrepancy is in time allocations for station operations and maintenance. Based upon yearly averages, these two activities each require about 5 man-hours/day. On a representative day, however, the time would be much less, and on days on which extensive maintenance is performed, the time would be in excess of the average.

In addition, the basic philosophy used for constructing the 48-hour activities precludes any unforeseen events which might result in maintenance other than that frequently scheduled. A second discrepancy exists in the time estimated for contingency/unassigned (14.4 man-hours/day, or 10%) and the actual, which ranged from approximately 17 to 18 man-hours/day. This occurred as a result of being unable to schedule every minute of each crewman's day with meaningful tasks.

Table 5-1

TIME REQUIREMENTS FOR A SIX-MAN CREW

Activity or Function	Day 1	Day 2	Baseline Estimates — 1 Day (Yearly Averages)
Personal maintenance			
Sleep	48.00	48.00	48.00
Food preparation, eating, and cleanup	11.90	12.00	12.00
Hygiene	4.80	4.80	4.80
Rest and relaxation	9.00	9.00	9.00
Basic biomedical monitoring (subject and observer)	4.00	4.00	4.00
Basic physical fitness (includes centrifugation-two subjects)	4.25	4.25	4.25
Operations	3.75	4.75	5.00
Maintenance	1.45	1.45	5.00
Transfer (station-to-station)	2.86	2.62	2.50
Contingency/unassigned	17.98	17.08	14.40
Engineering and scientific experiments and measurements	36.01	36.05	35.05
	144.00	144.00	144.00

After crew-time requirements were summarized, it was possible to assign specific tasks to individual crewmen and to proceed with the preparation of a 48-hour time line schedule. This analysis is discussed in Section 5.3. From these data, a matrix was prepared which indicates the assignment of task times to each of the six crewmen.

As a result of assessing the six-man crew's responsiveness to the 48-hour workload, it was concluded that six men can handle the workload but that a somewhat different skill mix from the baseline was required. These requirements stem from the nature of the 48-hour experiment workload which emphasizes physical science skills. Further, it is postulated that fewer hours would be devoted to biomedical and behavioral experiments during the 2nd year of the mission. Therefore, three experimental specialists, one of whom would be a life scientist, are indicated (instead of one physical scientist, one life scientist, and one medical specialist).

5.1 OPERATIONAL FUNCTIONS

Crew safety and well-being are dependent upon the proper accomplishment of operational functions; therefore, they were analyzed first. To determine the extent of crew involvement in these tasks, functional flow diagrams that considered only those events which would logically occur during any 2-day period were prepared for the operation and maintenance of each subsystem.

Figure 5-1 shows the functional flow of three tasks required by the environment control/life support system. These consist of daily verification and analysis checks, and they can be performed by one technician in any order and at any time during the 24-hour period. These tasks will require a total of only 8 min./day. Task 1 verifies the potability of the water supply, Task 2 is the routine monitoring of subsystem displays, and Task 3 is an atmosphere analysis. All three tasks will be performed on both Day 1 and Day 2, as required.

Operational procedures for the waste management system are shown in Figure 5-2. They will require about 7.5 min. of technician time for each of the two systems, or a total of 15 min./day. The same operation is repeated

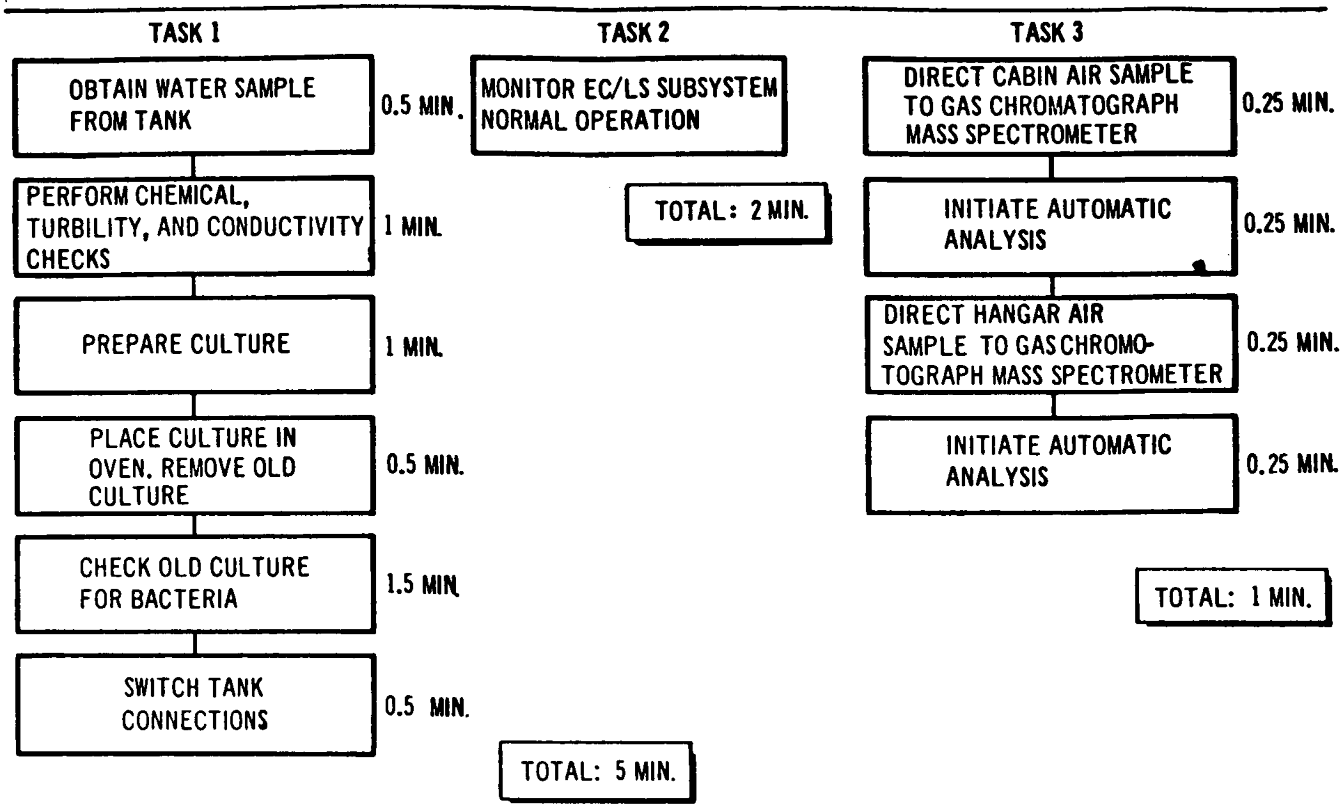


Figure 5-1. EC/LS System Operations

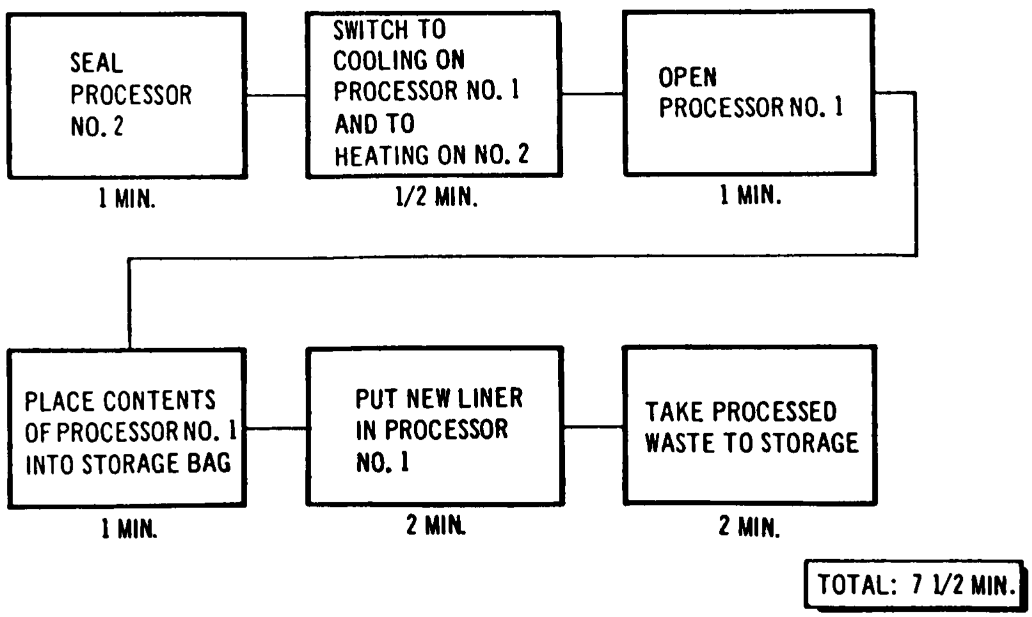


Figure 5-2. Operation of Waste Management System

on Day 2, except that the processes are reversed. The operation can be completed by one technician, who can perform other tasks during the wait period, if desired.

Stabilization and control operations require a maximum of seven 10-min. operations each day in support of the experimental program. One one-man operation consists of the manual procedures involved in the initial alignment of the star-tracker system. This operation is required prior to the experiments which need a stable platform, or any time the inertial reference system is turned on. The flow of these tasks is shown in Figure 5-3. These procedures will be followed five times on Day 1 and four times on Day 2.

Normally, the electrical power system operations will be performed once every two days. The procedures can be performed by one technician and will require a 14-min. period of crew time and a total elapsed time of 44 min. Essentially, this operation involves a check of the solar panels, batteries, and ac-dc buses for proper voltages, currents, and/or frequencies. These tasks are performed by one technician on Day 2 as shown in Figure 5-4.

It will take one technician 30 min. to complete the propulsion/reaction control system daily operations. These tasks, detailed in Figure 5-5, are broken down into four 5-min. tasks and one 10-min. task; all tasks can be accomplished by one technician. Primarily, the tasks involve a routine check of engine operation, temperature, pressure, relief valve, and supply tank level. All four tasks are performed on Day 1 and Day 2 as required.

Figure 5-6 indicates the three tasks required by the communication system for each ground communication opportunity. The steps involving the television monitor are shown for completeness, although they may not be required each time. The three tasks are subdivided according to pre-pass, pass, and post-pass circuits. The tasks can be accomplished by one technician utilizing 5 min. each for pre- and post-pass activities and varying times for pass activity (approximately 15 to 20 min.). There are five such opportunities on Day 1 and seven on Day 2.

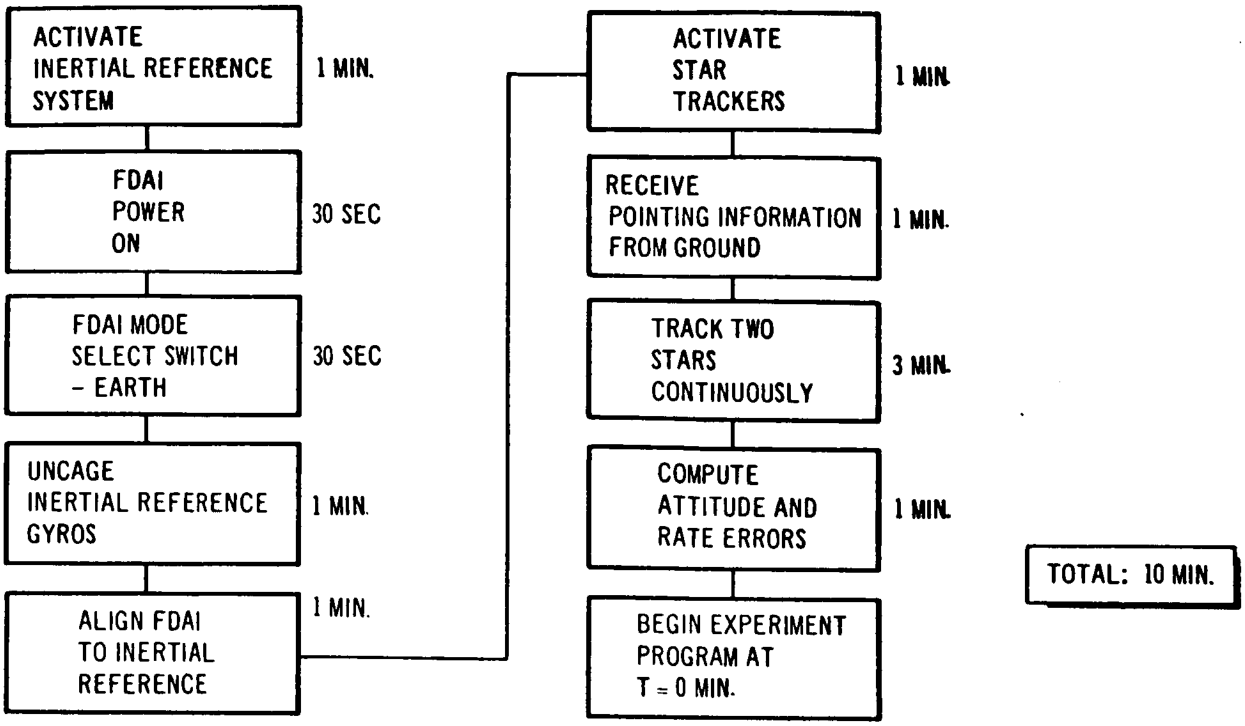
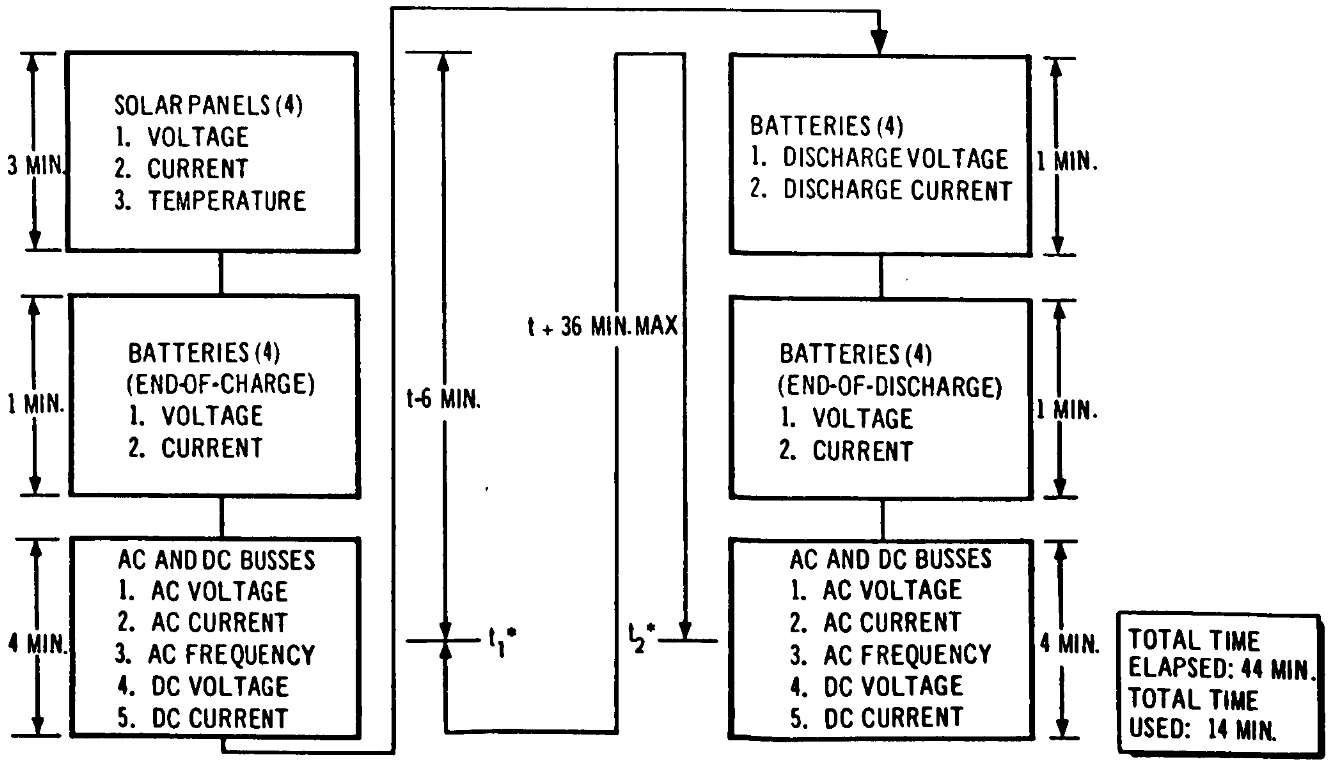


Figure 5-3. SCS Experimental Support – Initial Alignment



NOTE: *TRANSITION FROM SOLAR CELLS TO BATTERIES (t_1) AND FROM BATTERIES TO SOLAR CELLS (t_2)

Figure 5-4. Electrical Power System Operation (Once Every 2 Days)

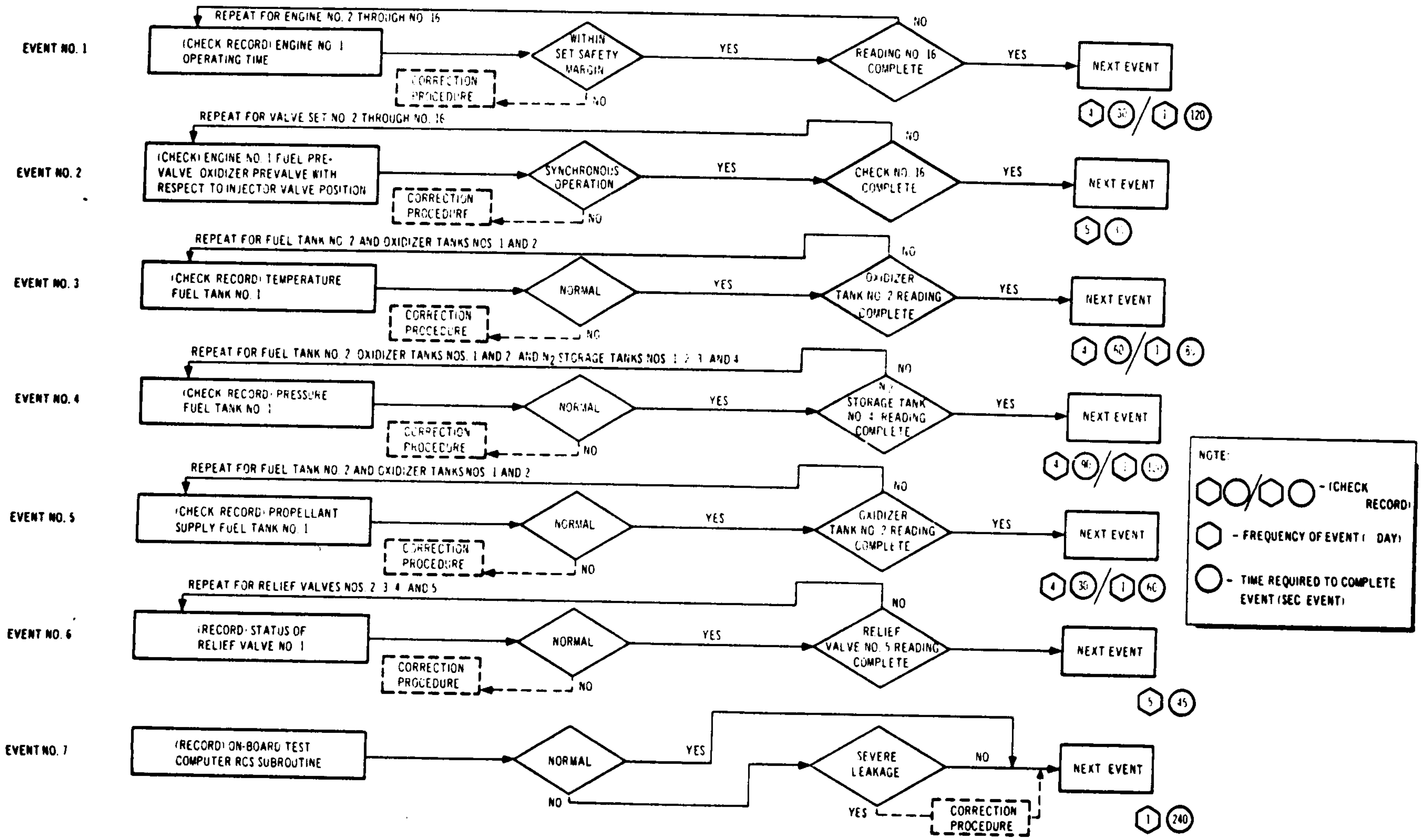


Figure 5-5. Propulsion/RCS Operational Events

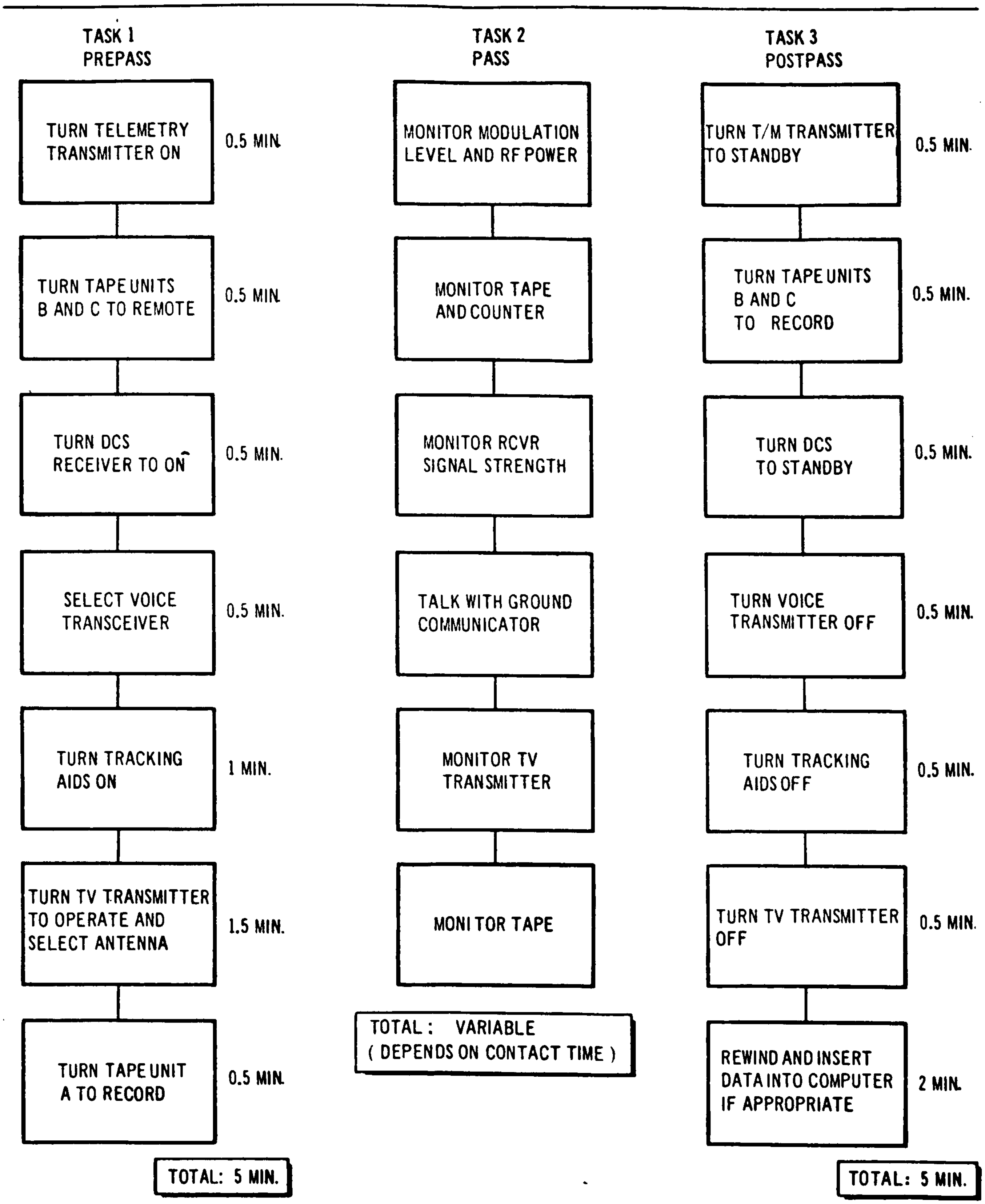


Figure 5-6. Communication with Ground

Routine test and maintenance activities were analyzed to provide a representative workload for these tasks. These activities include tape recorder cleaning, monitoring, and testing the batteries, and replacing the EC/LS system wick. They will consume a total of 3.4 man-hours for the 2-day period. Specifically, the three tape recorders will require periodic inspection and cleaning, which will take approximately 30 min./recorder every 3 or 4 days. This operation is shown in Figure 5-7, and it will occur on both Day 1 and Day 2. The procedures for maintaining the electrical power system require approximately 28 min. of crew time with the elapsed time varying according to the length of dark and light periods of the particular orbit. It should be noted that all batteries do not need to be monitored at the same time, but since equipment must be brought to the test location, it is advisable to test all batteries under normal maintenance operations at the same time. Monitoring frequency is every 1 to 2 weeks with the shorter interval near the end of battery life. For fault isolating, the cell will be monitored as required. These procedures will be performed on Day 2, as shown in Figure 5-8.

Maintenance of the EC/LS system consists mainly of changing the wick approximately every 2 weeks. Only 9 min. are required for a technician to perform this task. The procedure, outlined in Figure 5-9, will be completed on Day 2 only.

Food preparation, eating, and cleanup will require approximately 40 min./man/meal and will be repeated 3 times per day. The tasks involve primarily the reconstituting of foods, heating of certain foods, and disposing of waste products. These tasks are outlined in Figure 5-10.

Personal hygiene duties consist essentially of waste elimination, oral hygiene, shaving, bathing, and sponging. Because hair and nail cutting occur infrequently, they were not considered for the 40-hour period. The functional flow of these tasks is shown in Figure 5-11. The examples given are the tasks normally performed upon arising after an 8-hour sleep period.

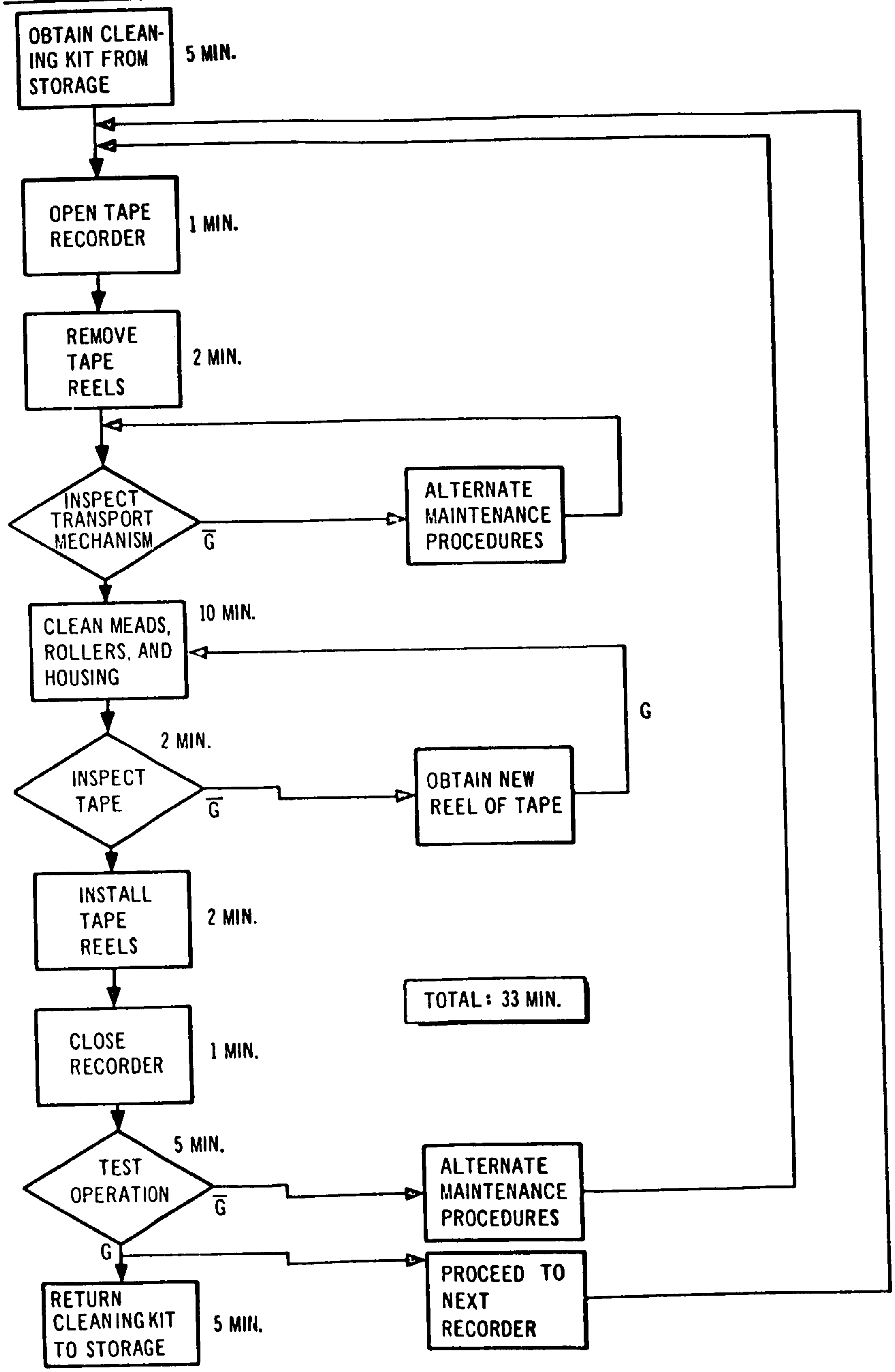


Figure 5-7. Tape Recorder Inspection and Cleaning

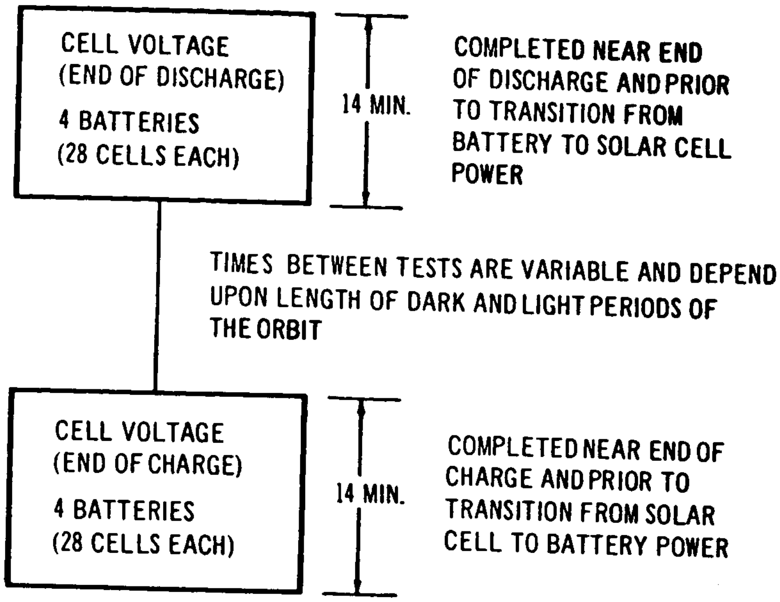


Figure 5-8. Maintenance Procedures for Electrical Power System

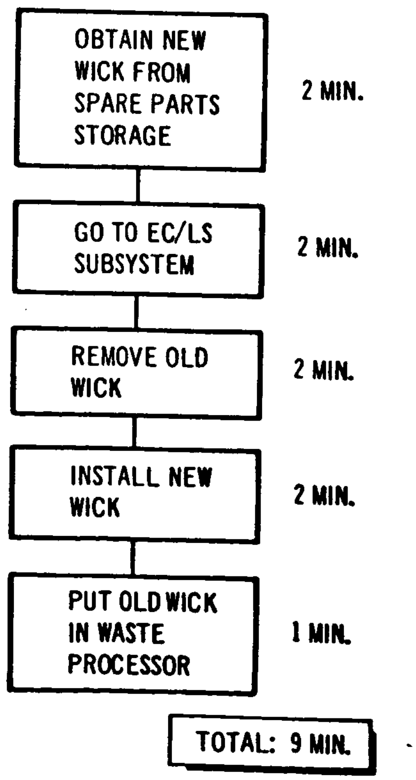


Figure 5-9. EC/LS Maintenance

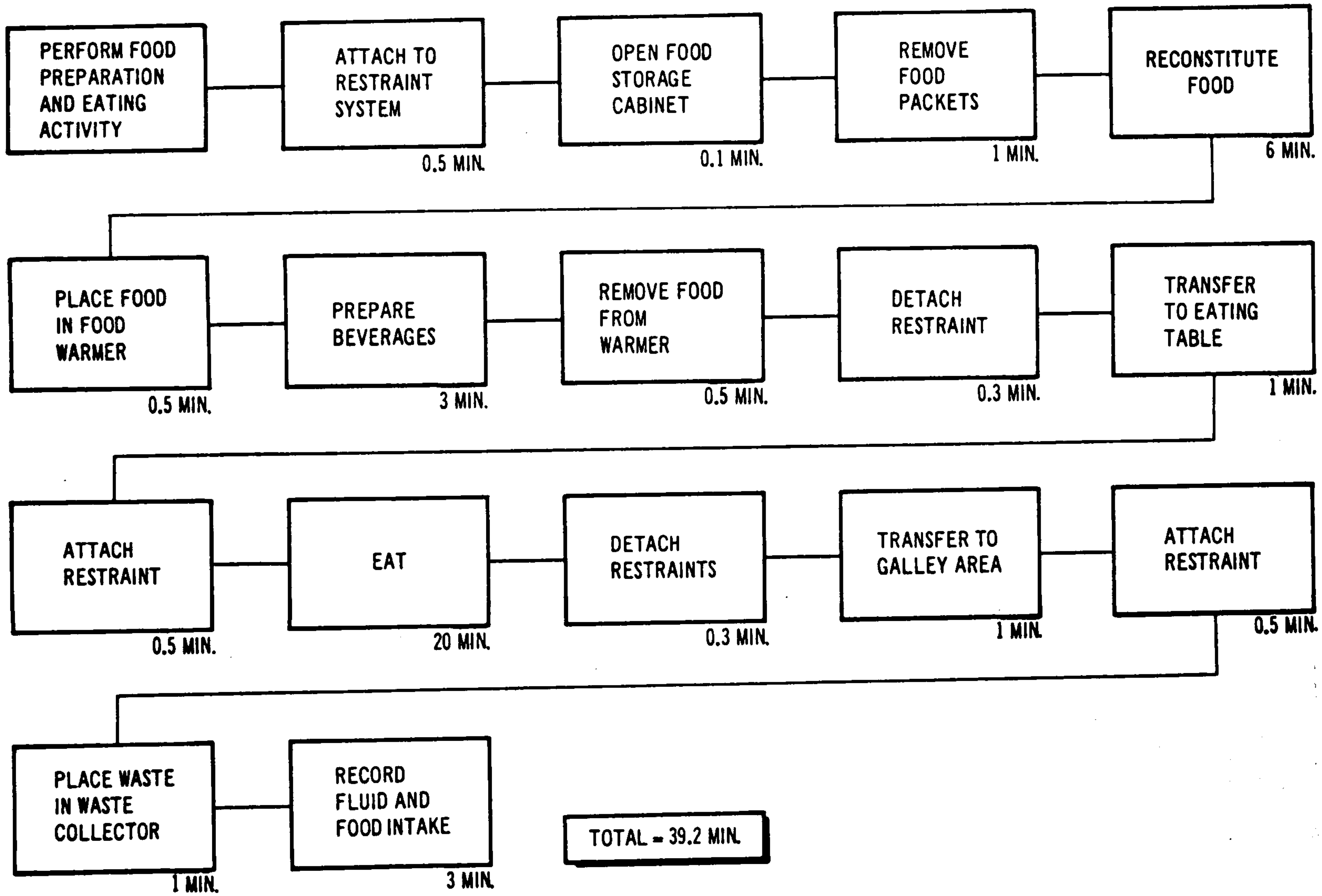


Figure 5-10. Food Preparation, Eating, and Cleanup

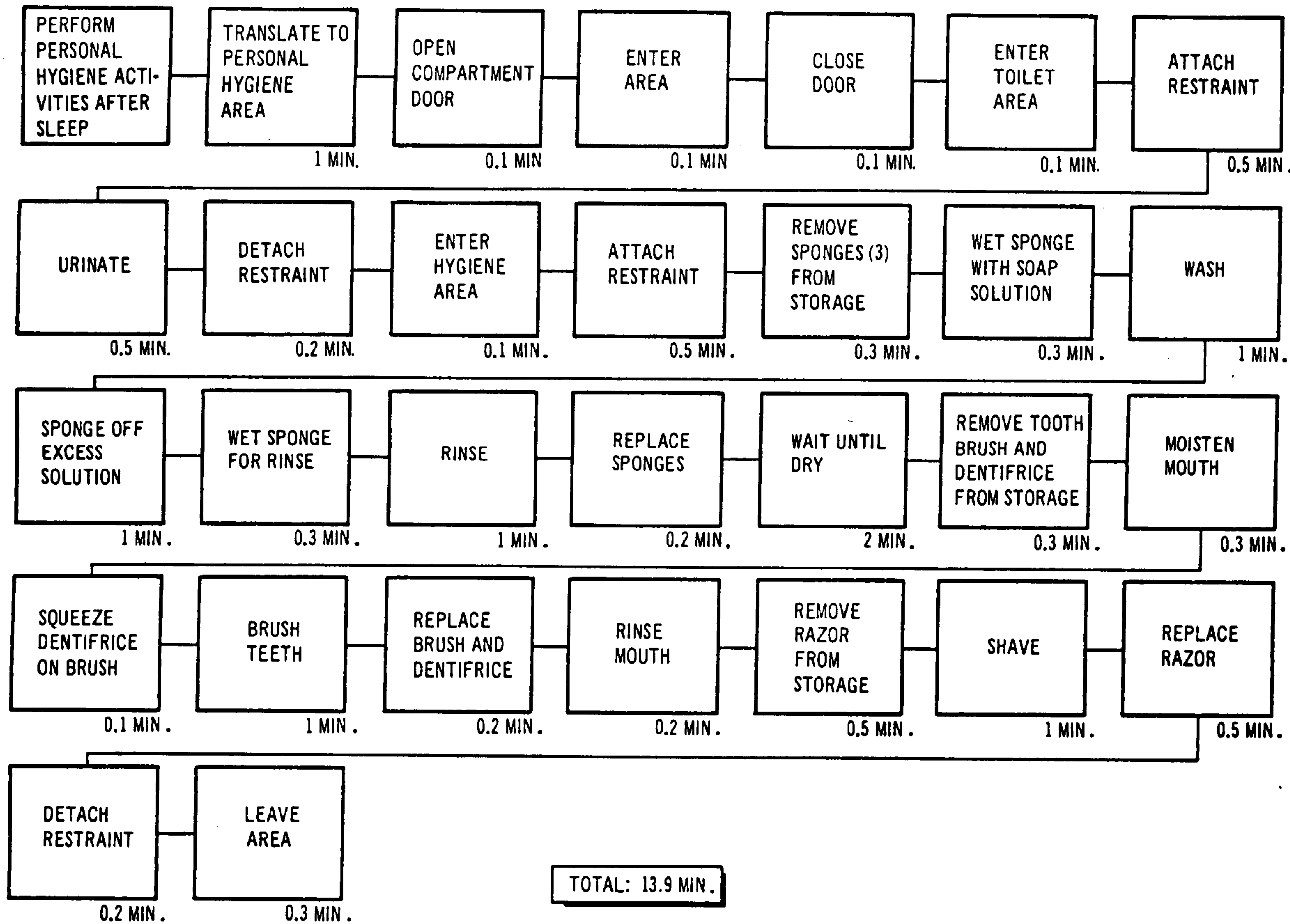


Figure 5-11. Personal Hygiene Activities After Sleep

The time allocated for rest and recreation to each crewman is 1.5 hours/day. The length of each period of rest or relaxation will vary from day to day according to workload constraints imposed by experimental or operational duties. A representative day would probably consist of three or four rest periods each day lasting from 0.15 to 1 hour each. Two examples of rest and relaxation procedures are shown in Figures 5-12 and 5-13.

Basic physical fitness procedures are provided in Figure 5-14. They will require approximately 0.5 hours/man/test. The procedures involve exercising the various body systems and quantitatively evaluating levels of fitness. Some crewmen are expected to be using the centrifuge for this purpose, which will take 45 min. of both subject and observer time.

Biomedical monitoring will consist of a daily routine of measuring basic parameters. The measurements will require approximately 30 min./subject/day and approximately 2 hours/day of biology technician time to record,

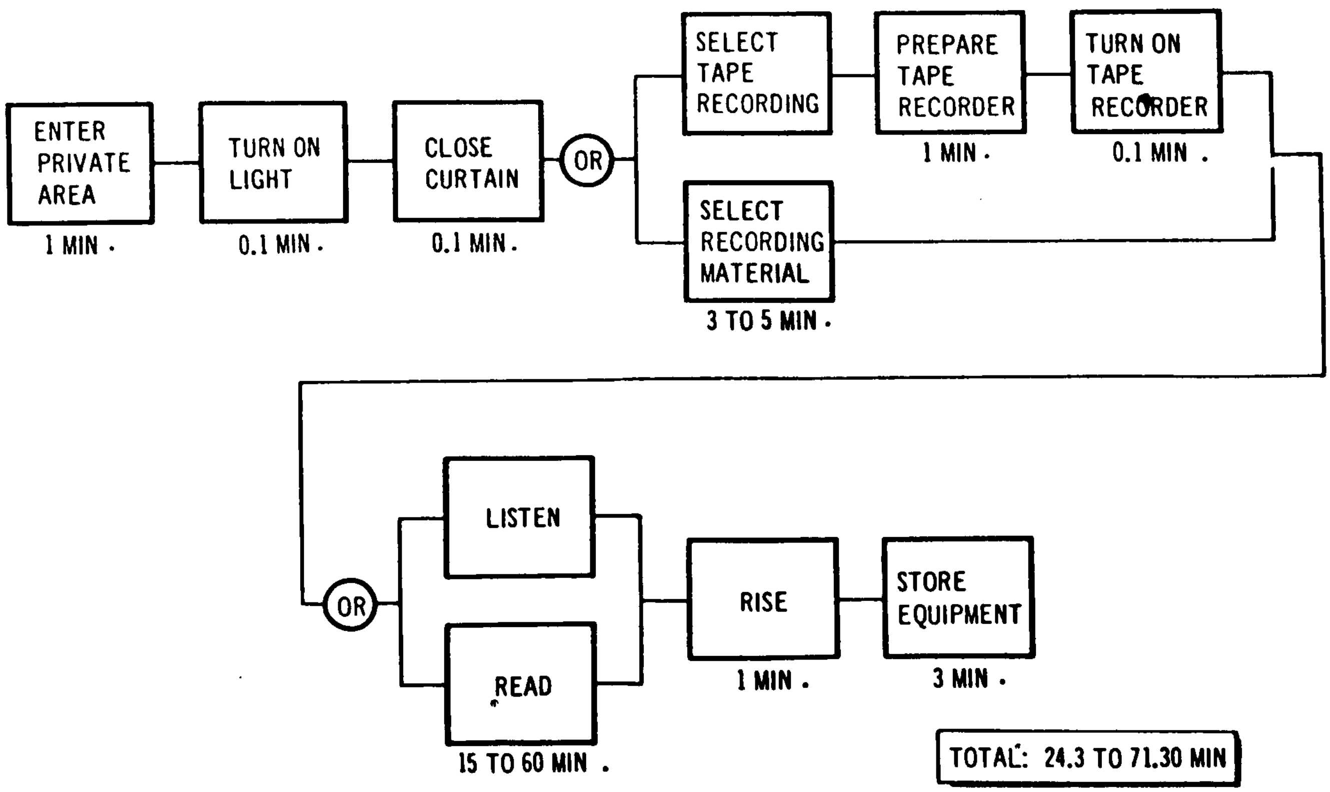


Figure 5-12. Rest and Recreation – Example No. 1

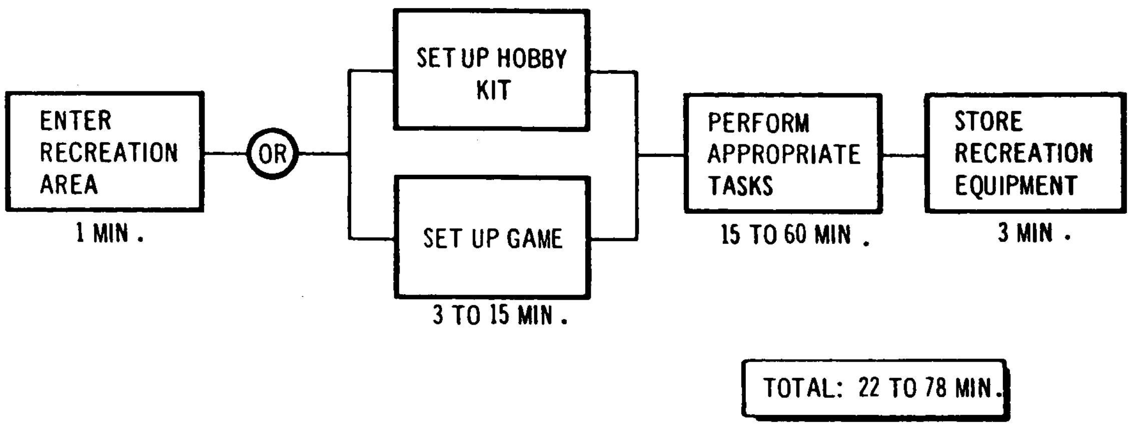


Figure 5-13. Rest and Recreation – Example No. 2

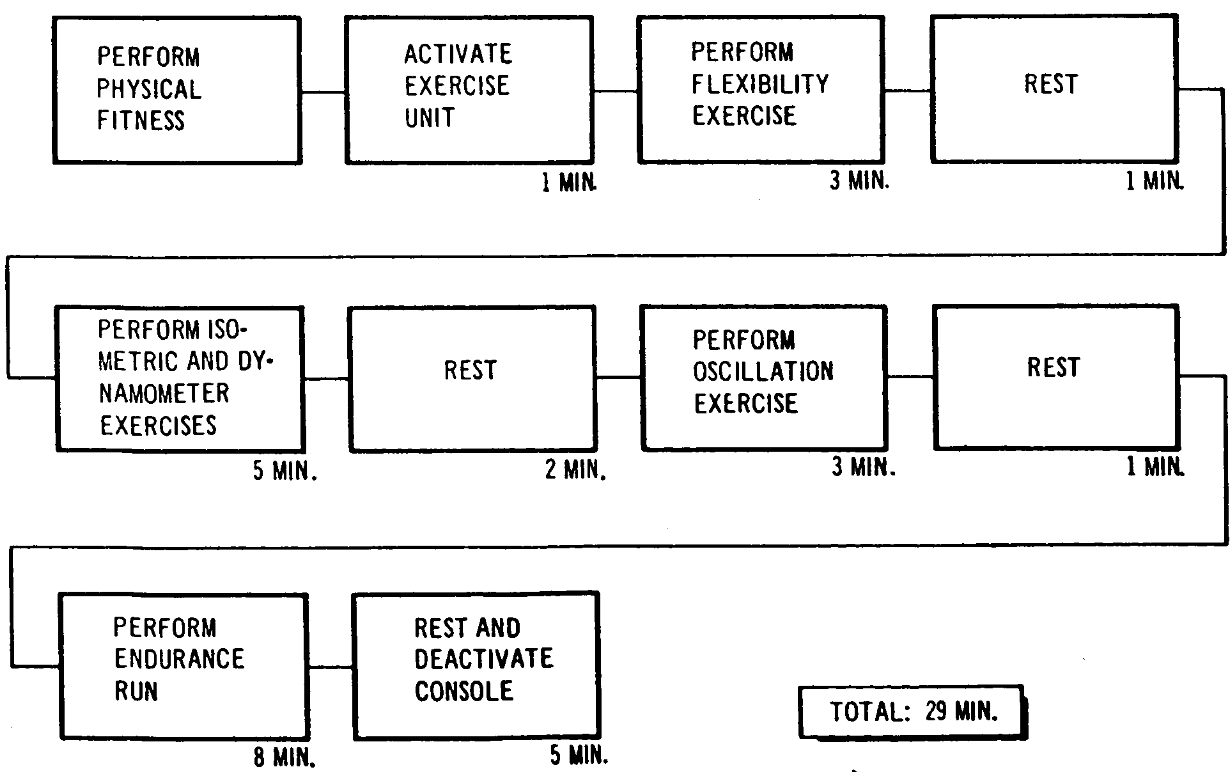


Figure 5-14. Physical Fitness Procedures

analyze, and interpret data. The parameters to be measured are outlined in Table 5-2. The functional flow of these activities is shown in Figure 5-15. They will require approximately 40 min./man/session.

No separate time has been allocated for behavioral monitoring, for these measures will be integrated into routine operations by the second year of the mission. There will undoubtedly be some behavioral testing and measurement, but these have not been identified and have not been considered in the 48-hour analysis.

An attempt was made to allocate a 10% contingency factory to each crewman's day to allow for unforeseen events or to permit the performance of tasks which occur so rarely that they are not normally scheduled. The final time allocations provided 14.33 man-hours of contingency for the first day and 13.43 man-hours for the 2nd day. Although this corresponds favorably to the baseline allocation of 14.4 man-hours/day, it has not been possible, or necessary, to distribute this time equally among all crewmen. The time is available for use as needed. In addition to the contingency factor, 3.65 man-hours of unassigned time is available each day. Unassigned time occurs whenever a crewman is free for a period of time that is too small to accomplish a given task or that occurs during an inopportune segment of his schedule. Only Experiment Specialist No. 3, the life scientist, does not have a period of unassigned time. This situation occurs because of his extensive workload and because he is frequently required to serve as an observer for short periods of time dispersed throughout the entire day.

Table 5-2

BASIC BIOMEDICAL MONITORING PROGRAM

Measure	Frequency (day)
A. Circulatory system	
1. Blood pressure	1
2. Heart rate and wave form	1
3. Pulse rate	1
4. Venous distention	1/10
B. Respiratory system	
1. Respiratory symptomology (dypsnea)	1/10
2. Respiratory rate	1
C. Thermoregulation	
1. Temperature	1
D. Neurological--musculo-skeletal system	
1. Nausea and regurgitation	1/10
2. Muscle size	1/10
E. Excretory System	
1. Urinalysis (WBC, RBC, pH, protein, sugar, bacteria, osmolarity)	1/10
2. Voiding evaluation	1
3. Bowel habits/functional evaluation and stool	1/3
F. Hematological	
1. Hematocrit	1/10
2. Hemoglobin	1/10
G. Nutrition	
1. Food intake (eating habits)	1
2. Fluid intake and output	1

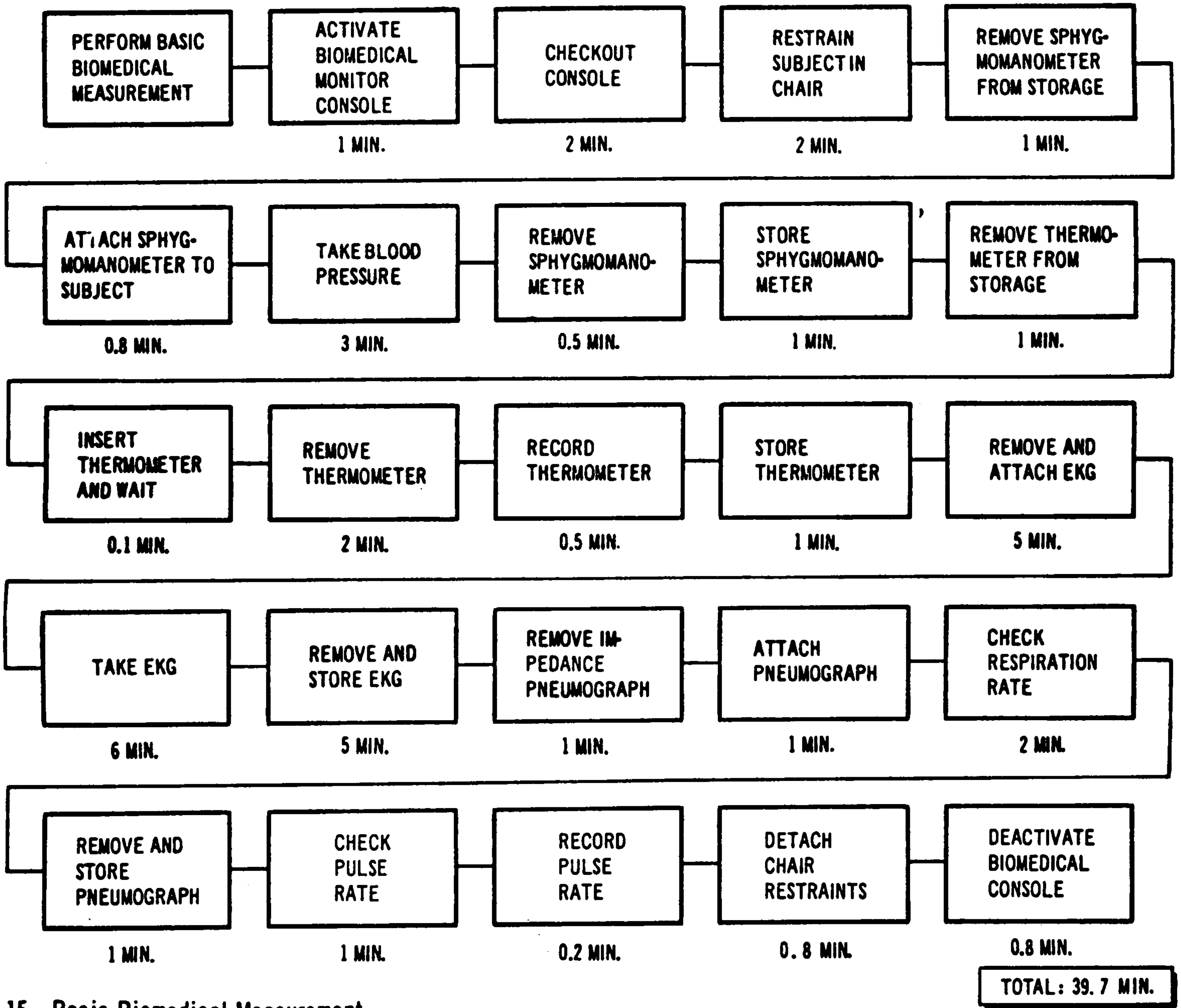


Figure 5-15. Basic Biomedical Measurement

5.2 EXPERIMENT FUNCTIONS

Of the 18 experiments selected for the 48-hour study, 14 are in the areas of space sciences (astronomy/astrophysics, biological sciences, and physical sciences) and support for space travel (advance technology and supporting research). The experiments chosen are representative of an experiment program occurring during the second or subsequent year of the MORL mission. A variety of experiment areas was chosen to help establish the degree of flexibility potential available on board the laboratory.

The first step in the analysis of the impact of the experiment requirements on the baseline system was to prepare task flow diagrams for each experiment or measurement area. From these diagrams, crew requirements and man-equipment interface problems were derived. The crew requirements for the 18 experiments are summarized below, and task flow diagrams are provided for each. The experiment descriptions are contained in the appendix.

5.2.1 Design Evaluation and Approval Tests of Final Radar Equipment (Applications Plan Task No. 252)

Detailed tests required by this experiment are shown in functional flow diagram form in Figure 5-16. Additionally, a detailed task sequence, along with revised time estimates indicating events in more detail, is shown in Table 5-3. Three flight crew members will be required to install the radar antenna on the external surface of the vehicle. Approximately 15 man-hours will be required to accomplish this installation. Two crewmen will perform the installation procedures, and one crewman will be standing by in the air-lock prior to the installation procedures; the crew will preassemble the antenna components to minimize extravehicular procedures. Additionally, they will install and calibrate the internally mounted equipment.

Following setup, they will operate the radar, collecting synoptic data over preselected targets in the vicinity of the continental United States. Sea-state data will be compared with data collected by instrumented sea-surface measurements, thereby verifying the capability of the radar to perform this function. Operation of the radar for this purpose will occupy one technician

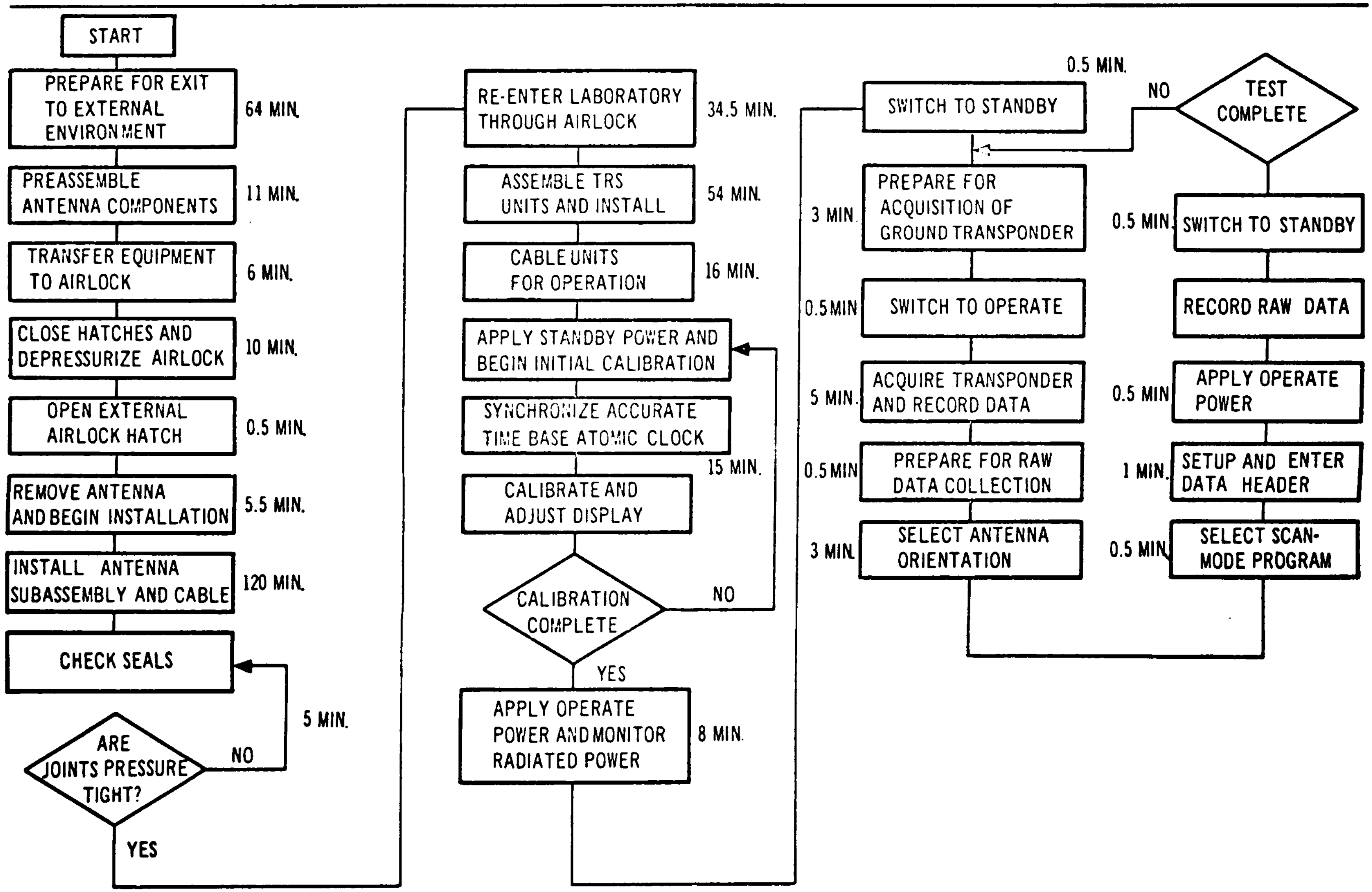


Figure 5-16. Design Evaluation and Approval Tests of Final Radar Equipment

Table 5-3

REVISED TIME ESTIMATES FOR EXPERIMENT 252 – RADAR
(page 1 of 3)

Events	Elapsed Time	Skill	Crewmen 1	Crewmen 2	Crewmen 3
			12	11	Any
Arrive at operations deck	0		0	0	0
Enter hangar	6		6	6	--
Remove experiment from rack	11		5	5	--
Bring experiment to operations deck	17		6	6	--
Remove antenna assembly from box	18		1	1	--
Obtain three suits from rack	24		--	--	6
Proceed to living area	24		6	6	--
Preassemble antenna components	35		11	11	--
Proceed to living area	35		--	--	6
Open aft airlock hatch	36		--	--	1
Transfer equipment to aft airlock	42		6	6	--
Don spacesuits	47		5	5	5
Denitrogenate*	92		45	45	45
Check for proper operation	97		5	5	5
Enter aft airlock	99		2	2	2
Close hatch	100		1	--	--
Check aft airlock seal (visual)	102		2	--	--
Connect to airlock suit loop	103		--	--	1
Check operation	105		--	--	2
Reduce pressure in aft airlock	119		14	--	--
Verify pressure seal	120		1	--	--
Verify pressure equalized	121		1	--	--
Open external hatch	122		--	1	--
Exit aft airlock	126		4	4	--
Proceed to exit position	129		3	3	--
Secure and check walk lines	131		1	2	--

*Must be just prior to completion of spacesuit donning, that is, with suits unpressurized, and face mask open.

Table 5-3 (page 2 of 3)

			Crewmen		
			1	2	3
Events	Elapsed Time	Skill	12	11	Any
Proceed to installation area	136		5	5	--
Secure positions and antenna assembly	137		1	1	--
Remove antenna and begin installation	142		5	5	--
Install antenna and cable	262		120	120	--
Check seals	267		5	5	--
Disengage secure ties and antenna box	268		1	1	--
Proceed to aft end of laboratory	273		5	5	--
Enter aft end and disengage walk lines	275		1	2	--
Proceed to aft airlock	278		3	3	--
Enter aft airlock	280		2	2	--
Close hatch	281		1	--	--
Check seal (visual)	282		1	--	--
Repressurize	283		--	--	1
Check seal	285		--	--	2
Verify pressure equal	286		1	--	1
Disconnect suit loop	287		--	--	1
Open hatch	288		--	--	1
Exit airlock	290		2	2	2
Depressurize suits	291		1	1	1
Remove and store suits	297		6	6	6
End extravehicular activities; crewmen now go off duty (that is, take care of personal hygiene, eating, etc.)					
Arrive at operations area	0				
Check remaining components	5		--	5	
Prepare console for installation	5		5	--	
Install assembly in console	10		10	10	
Secure to baseplate	14		4	END	

Table 5-3 (page 3 of 3)

Events	Elapsed Time	Skill	Crewmen 1 (12)	Crewmen 2 (11)	Crewmen 3 (Any)
Load data recorder	22		8		
Connect cables	38		16		
Internal installation complete					

Events	Elapsed Time	Crewman 4
Arrive at operations area	0	
Proceed to front of console	1	1
Operate and calibrate time	1	1
Adjust sync for lock	7	6
Calibrate and adjust display	15	8
Calibration complete	16	1
Measure radar power	24	8
Switch to standby	25	1
End setup and calibration		

SUMMARY

Crewman			
1	297 + 38	= 335 min.	= 5.6 hours
2	297 + 15	= 312 min.	= 5.2 hours
3	297	= 297 min.	= 4.9 hours
4	25	= 25 min.	= 0.4 hours
			16.1 hours

Additionally, each experiment run cycle is 34 min. long: 6 cycles = 204 min.

for 3.45 hours per test. During the 48-hour period, four crewmen are involved in the experiment and will expend approximately 19 man-hours completing the tasks.

5.2.2 Design Evaluation and Approval Tests of Variable Focal Length, High-Speed, Large-Format Camera (Applications Plan Task No. 255)

There are three parts to this experiment. The first, shown in Figure 5-17, involves the processing of both black-and-white and color films. Basically, the process is automatic, but a technician will be required to manually start the processing equipment, such as heaters and mixers, to load and start the processor, and to transfer film for the drying process. In addition, this technician will monitor the automatic process cycle and, finally, clean the processor and maintain it in an operable condition.

The second part of the experiment consists of target selection, setup and calibration of photographic equipment, and monitoring of automatic camera functions. These tasks are shown in Figure 5-18. Other crew tasks include inserting target data into the programmer and coordinating data from the ground with the tests. The photo technician/cartographer will change lenses, filters, and films as required by a particular test run.

The third part of the experiment, outlined in Figure 5-19, pertains to the analysis of processed films. A photo technician/cartographer will load a projector, select frames of interest, and analyze each as required. He will also indicate which frames are to be transmitted to Earth for further analysis.

The total time to complete all three parts of the experiment is approximately 19 man-hours. Because this is a rather extensive set of procedures to complete within a 48-hour period, the tasks should be distributed among several crewmen.

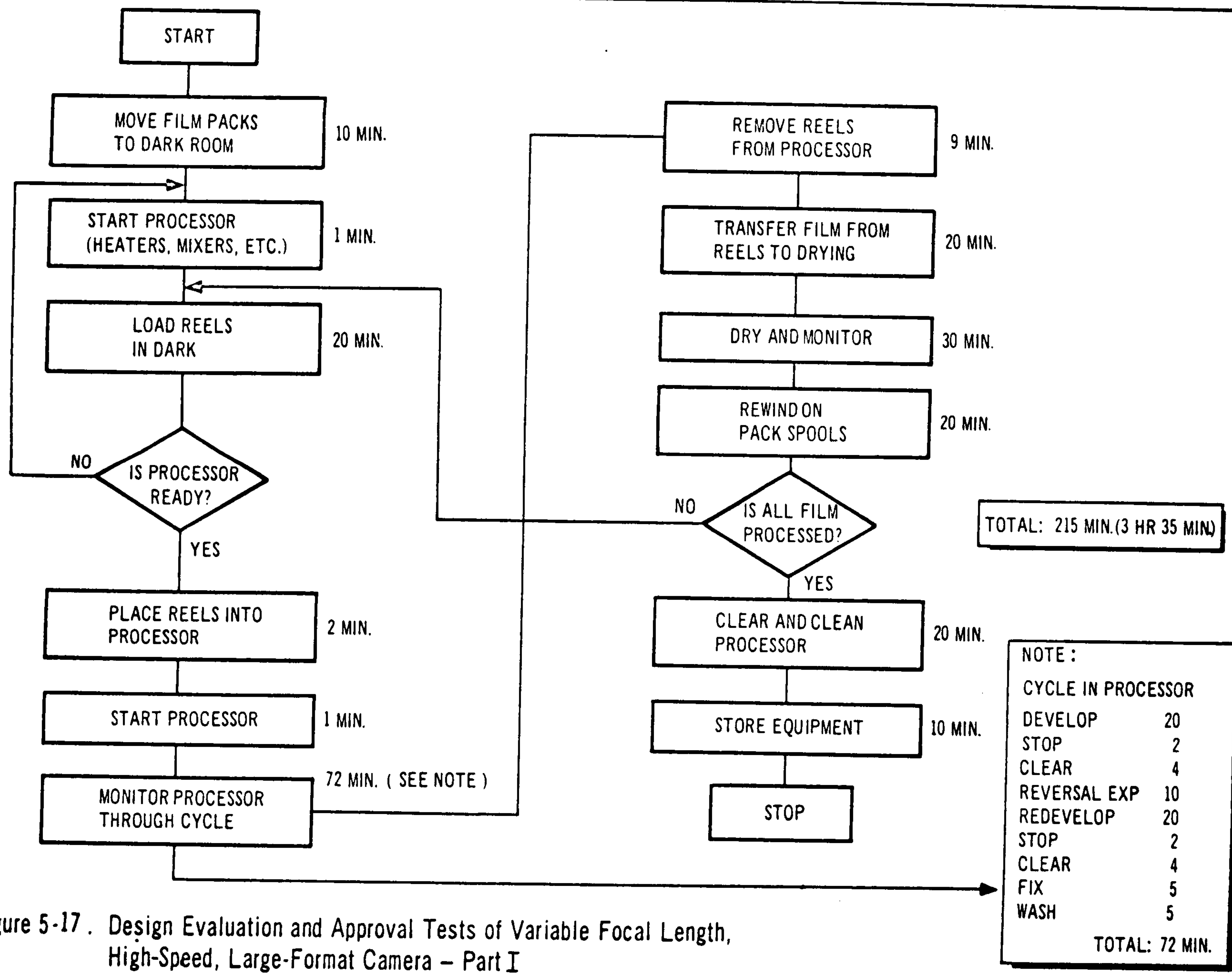


Figure 5-17. Design Evaluation and Approval Tests of Variable Focal Length, High-Speed, Large-Format Camera – Part I

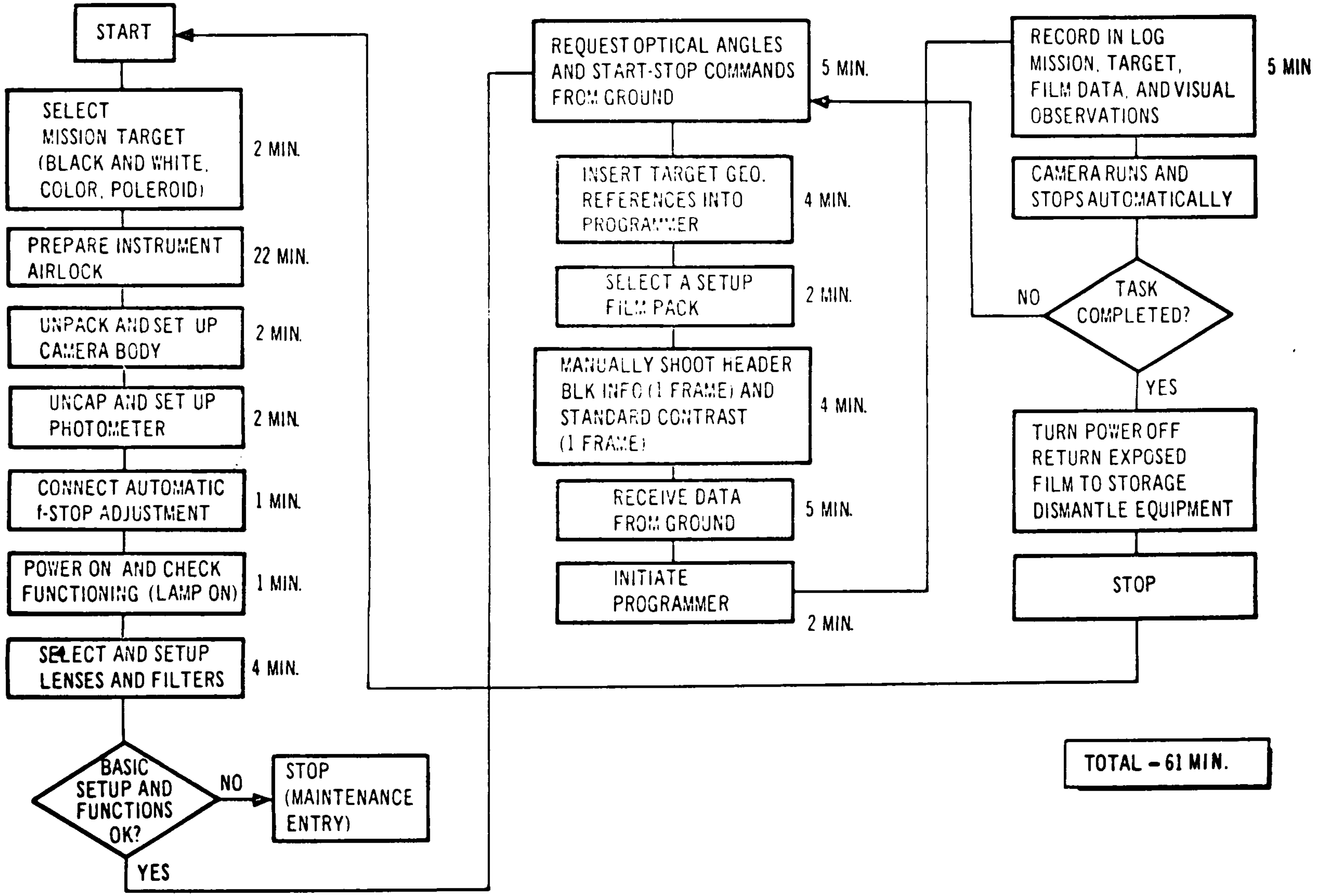


Figure 5-18. Design Evaluation and Approval Tests of Variable Focal-Length, High-Speed, Large Format Camera – Part II

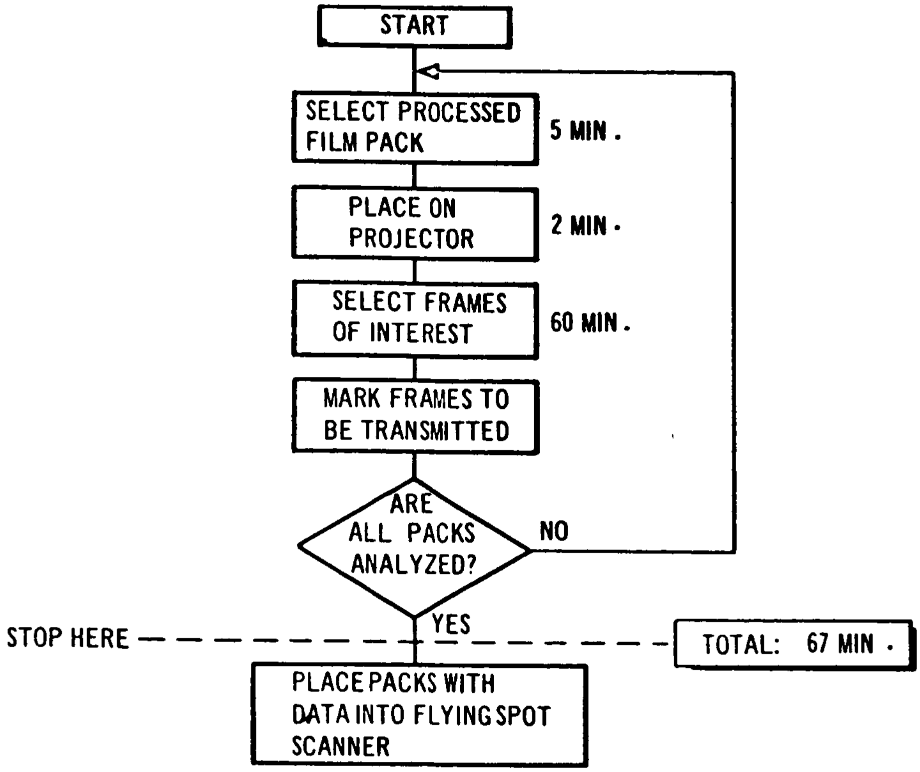


Figure 5-19. Design Evaluation and Approval Tests of Variable Focal-Length, High-Speed, Large-Format Camera – Part III

5.2.3 Design Evaluation Tests of Microwave Radiometers (Applications Plan Task No. 256)

For this experiment, the crew will be required to assemble and install two antennas on the external surface of the vehicle. Also, they will install and calibrate associated internally mounted equipment. Once the equipment is operable, the crew will operate the radiometer, gathering synoptic data over preselected targets in the vicinity of the continental United States.

For the purposes of the 48-hour analysis, it has been assumed that equipment installation has been accomplished. Therefore, only crew involvement in collecting data was analyzed. These tasks are shown in Figure 5-20. One electromechanical technician will spend approximately 1.7 hours completing this task on Day 1. His primary responsibility consists of acquiring orientation angles, coordinating command data from the ground, and monitoring the automatic test functions.

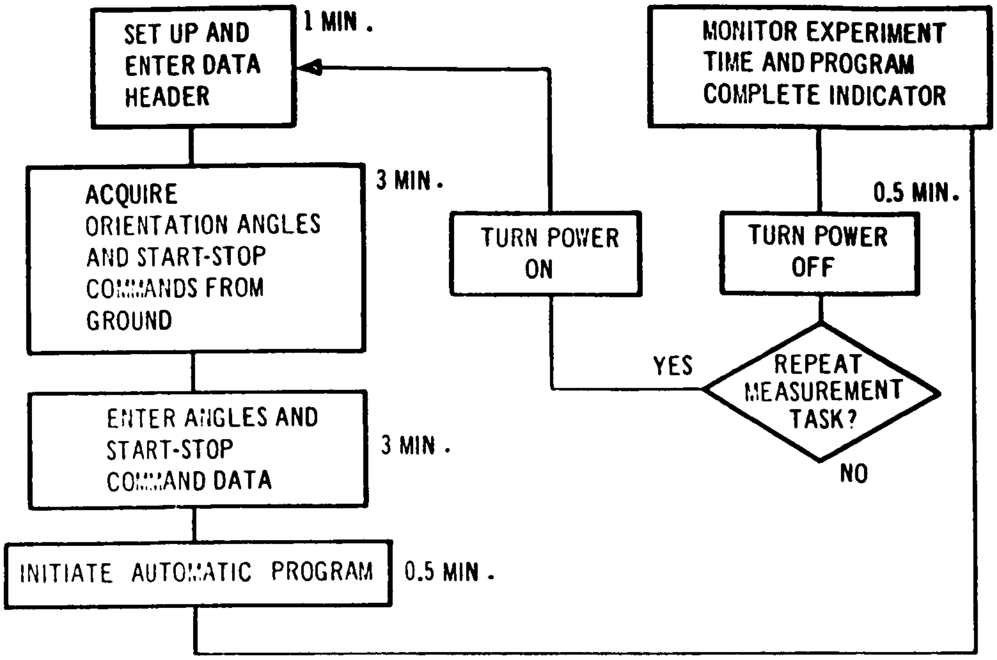


Figure 5-20. Design Evaluation Tests of Microwave Radiometers

5.2.4 Design Evaluation Tests of Infrared Radiometers (Applications Plan Task No. 257)

The crew will be required to assemble and install an infrared sensor on the external surface of the vehicle. They will also install and calibrate the internally mounted equipment. For the 48-hour analysis, these operations are assumed to be complete. Crew involvement is limited to operating the radar and collecting synoptic data at preselected targets in the vicinity of the continental United States.

Figure 5-21 indicates the procedural steps for an optical technician. Basically, he will acquire optic orientation angles, enter angles and start-stop command data from the ground, and initiate and monitor the automatic functions. He will spend 3.7 hours during the 48-hour period.

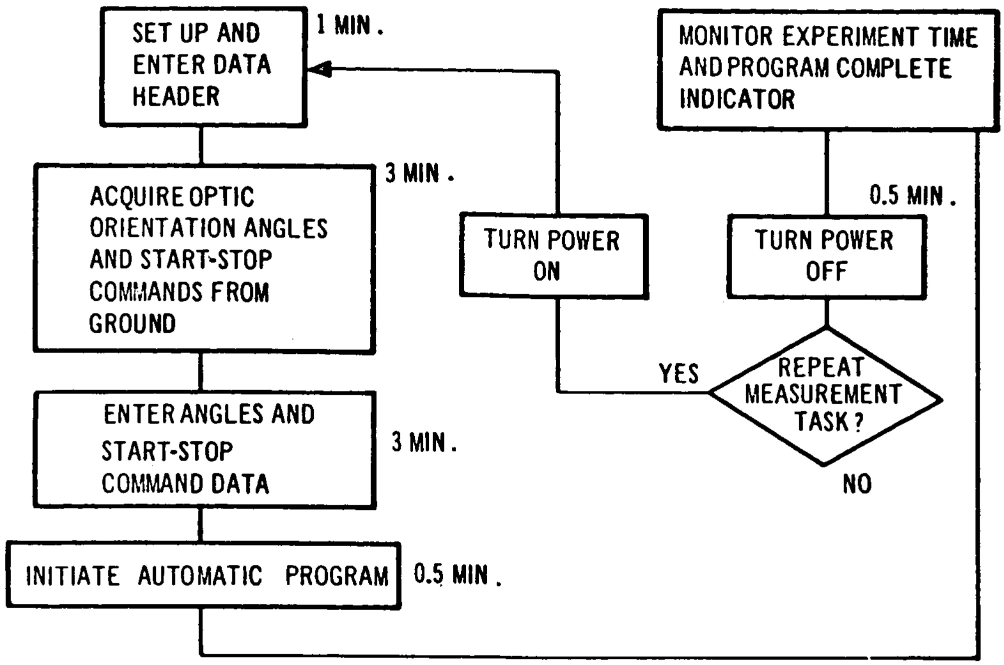


Figure 5-21. Design Evaluation Tests of Infrared Radiometers

5.2.5 Cosmic Dust Measurement (Data Bank Experiment No. IA-1)

First, the crew will be required to unpack, assemble, checkout, and calibrate the sensing equipment. Then they will install the sensors extravehicularly and initiate the testing operations. Additional responsibilities will include calibration checks, which will be performed approximately every 2 weeks, and monthly inspection and orientation change of the panels. In addition, amplifier sensitivity must be adjusted periodically from inside the laboratory. Repair will consist of substituting a complete detector assembly, motor, or motor control. During the tests, one technician will be required to make required changes to mast and swivel by appropriate, manually activated mechanical drive. This task will require 15 min./test and is scheduled for Day 1. These tasks are sequentially shown in Figure 5-22 and are performed at the scientific experiment console.

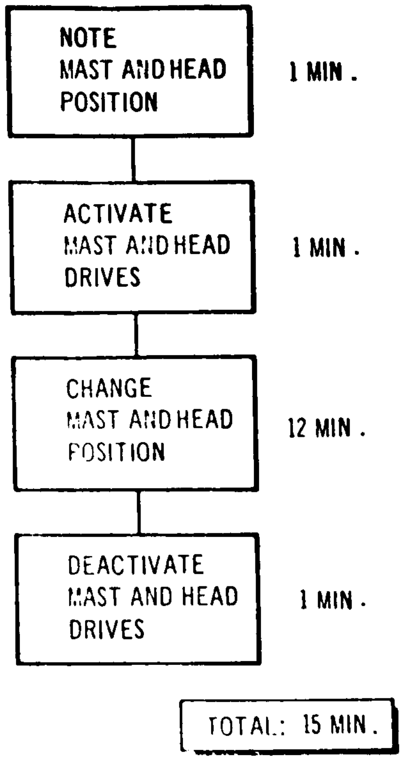


Figure 5-22. Cosmic Dust Measurement

5.2.6 Effects of High-Energy Particulate Radiation on Selected Living and Nonliving Materials (Data Bank Experiment No. IB-23)

For comparative purposes, three sets of samples will be stored and exposed for the life of the laboratory. One set will be stored in a flight-mounted storm stellar and will not require any flight crew activity. A second set will be exposed to the environment inside the laboratory, and a third to the external environment. These will require daily observations by a technician who will note any observable changes in the specimens. This task, outlined in Figure 5-23, will require 15 min./day.

Initially, the crew will install the internally positioned specimens in a pre-determined location. Care should be observed in handling the specimens which are stored in quartz tubes. The externally mounted specimens will be placed by the crew in a convenient location near the airlock. Only the retrieval of specimens will require extravehicular activity, since a view port will permit crew inspection from inside the laboratory.

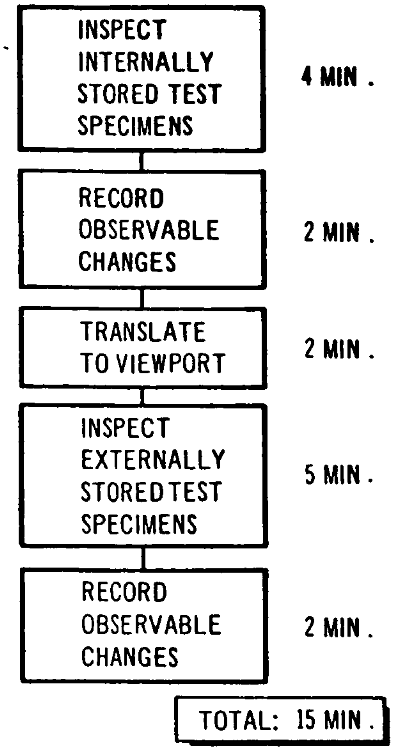


Figure 5-23. Effects of High-Energy Particulate Radiation on Selected Living and Nonliving Materials

5.2.7 Measurements of Solar Absorptivity and Thermal Emissivity of Various Materials by Spectrometry (Data Bank Experiment No. IIIB-6)

This measurement is accomplished by exposing various materials to the orbital environment and by analyzing the changes in the ratio of solar absorptivity to thermal (infrared) emissivity. The general procedure is to expose selected metal and coated-metal specimens to the space environment and then periodically to determine the total thermal emittance and total solar absorbance by calorimetric measurements. The crew will be required to bring specimens, or parts of specimens, into the laboratory for spectral reflectance and for physical and chemical analyses. The crew will then return the specimens to the external rack for further exposure. In some instances, the crew may also be required to select, package, and return specimens to the ground for further analysis.

When required, the extravehicular activity of inspecting specimens and equipment and of retrieving samples will require one technician and one observer for an estimated 116 min. The first part of these tasks is shown in Figure 5-24. Figure 5-25 indicates the procedures to be followed in making the reflective measurements. This task requires one technician for approximately 30 min./test. The installation procedures of external samples are shown in Figure 5-26. This task will require one technician and one observer for 30 min. Finally, the calorimetric test of samples is outlined in Figure 5-27. This test will occupy one technician for an estimated 65-min. period. He will apply measurement equipment to the samples, record data, calibrate and check coolant equipment, monitor progress of the test, and record the results. For the 48-hour analysis, only the daily observation of specimens is considered, and this will require one technician for 0.1 hour. Because of the simplicity of the task, it is not shown in diagram form.

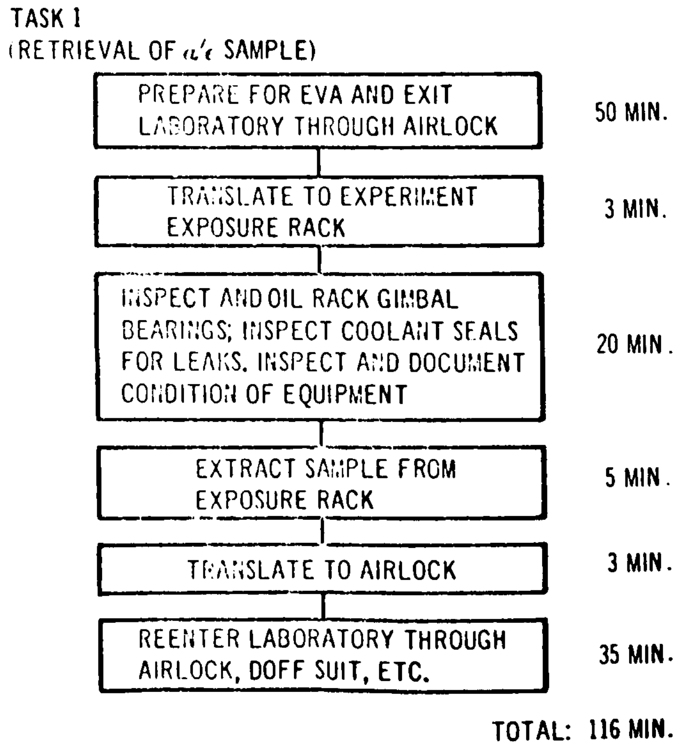


Figure 5-24. Measurement of Solar Absorptivity and Thermal Emissivity of Various Materials by Spectrometry – Part I

TASK 2
(TEST OF α/ϵ SAMPLE)

TRANSLATE TO ANALYTICAL STATION	1 MIN.
SET UP SPHERICAL REFLECTOMETER EQUIPMENT AND RECORDING EQUIPMENT AND CALIBRATE	13 MIN.
INSTALL/SAMPLE IN TEST APPARATUS	2 MIN.
MAKE MEASUREMENTS, TAKE AND RECORD DATA	10 MIN.
DISASSEMBLE AND STORE TEST APPARATUS	3 MIN.

TOTAL: 29 MIN.

Figure 5-25 . Measurement of Solar Absorptivity and Thermal Emissivity of Various Materials by Spectrometry – Part II

TASK 3
(INSTALL α/ϵ SAMPLE FOR EXPOSURE)

SUIT UP, DENITROGENATE, AND EXIT LABORATORY THROUGH AIRLOCK	NO TIME – ASSUME PART OF ANOTHER CONVENIENT EVA
TRANSLATE TO EXPOSURE RACK	2 MIN.
INSTALL SAMPLE ON EXPOSURE RACK	18 MIN.
REENTER LABORATORY	NO TIME – ASSUME PART OF THE OTHER EVA

TOTAL: 20 MIN.

Figure 5-26 . Measurement of Solar Absorptivity and Thermal Emissivity of Various Materials by Spectrometry – Part III

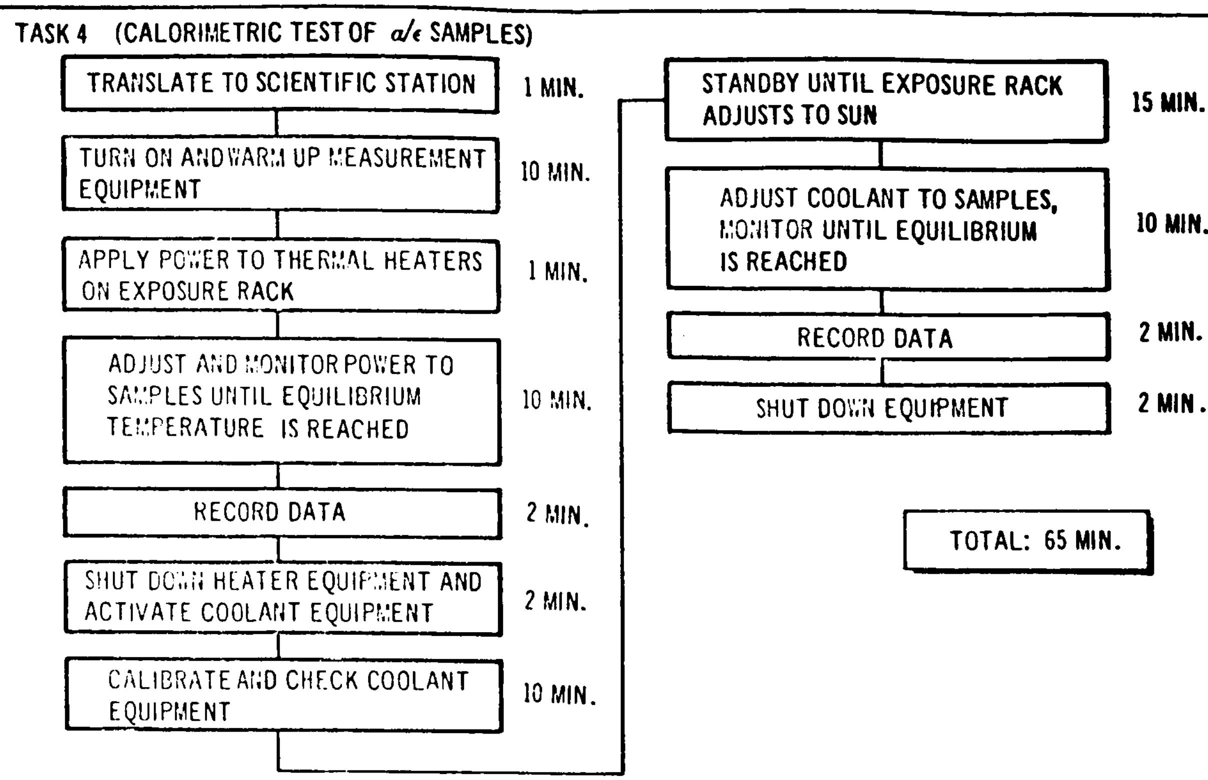


Figure 5-27. Measurement of Solar Absorptivity and Thermal Emissivity of Various Materials by Spectrometry – Part IV

5.2.8 Space Vehicle Equilibrium Study (Data Bank Experiment No. IC-15)

For this study, the crew is required to record on tape their level of activity during specified periods of time and to correlate this with thermal conditions in the vehicle. Periodically, the crew might adjust various ECS controls to obtain data for unusual situations. These data will be recorded automatically. The results of the study will aid in determining the effectiveness of thermal analysis methods used in the design of environmental control systems. Daily tests will require one technician for 12 min. (see Figure 5-28).

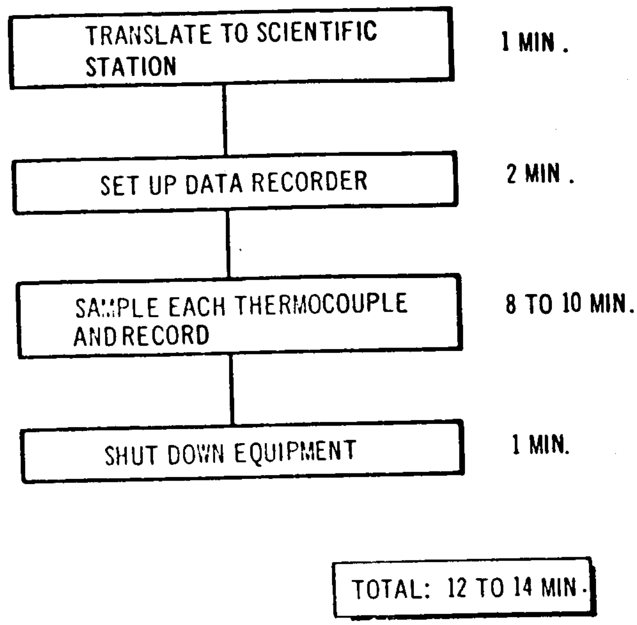


Figure 5- 28 . Space-Vehicle Equilibrium Study

5.2.9 Evaluation of Communication Techniques (Data Bank Experiment No. IIC-1)

The purpose of this experiment is to investigate the problems and physical phenomenon associated with communications from spacecraft to ground, from ground to spacecraft, from spacecraft to spacecraft, from spacecraft to aircraft, from logistics vehicle to ground, and from ground to ground. The crew will participate principally by setting up appropriate receiving equipment configurations and selecting data to be transmitted to the ground. The crew will check operation of equipment and sort results of various tests.

One technician (for example, a radar or microwave specialist) will spend approximately 80 min./day performing the functions shown in Figure 5-29. In addition to routine operations and maintenance of equipment, he will select appropriate receiving frequencies, compare results of tests with standard, and sort and record results. The tasks will be performed at the operations console, and all equipment, except for the antenna, is mounted internally.

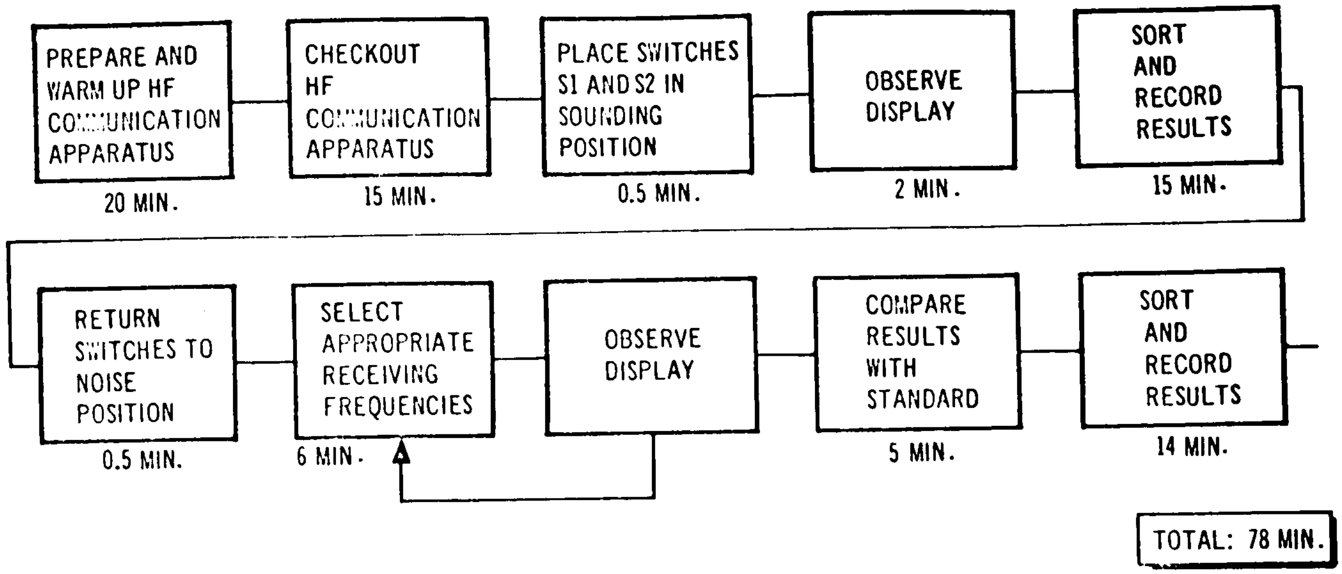


Figure 5-29. Evaluation of Communication Techniques

5.2.10 Fatigue Tests of Materials After Exposure to Space Environment (Data Bank Experiment No. IIIB-3)

The crew will install one testing machine externally, and will mount metallic specimens in various positions on the external skin of the vehicle. Periodically, they will retrieve some specimens for testing inside the laboratory. Certain specimens will be vacuum bottled and returned for testing in the Earth environment. The crew will manually control external testing from inside the laboratory. They will also visually inspect the specimens and record results and observations. The procedures are shown in Figure 5-30. The steps involved in inspecting and retrieving samples extravehicularly are presented. This operation will use one technician and one observer for approximately 1 hour.

Figure 5-31 illustrates the procedures required to install a test machine in the experiment airlock and to expose test coupons to the external environment through an extender plate. He will conduct a test of these coupons and remove and stow the test machine. This operation will require one technician for 35 min.

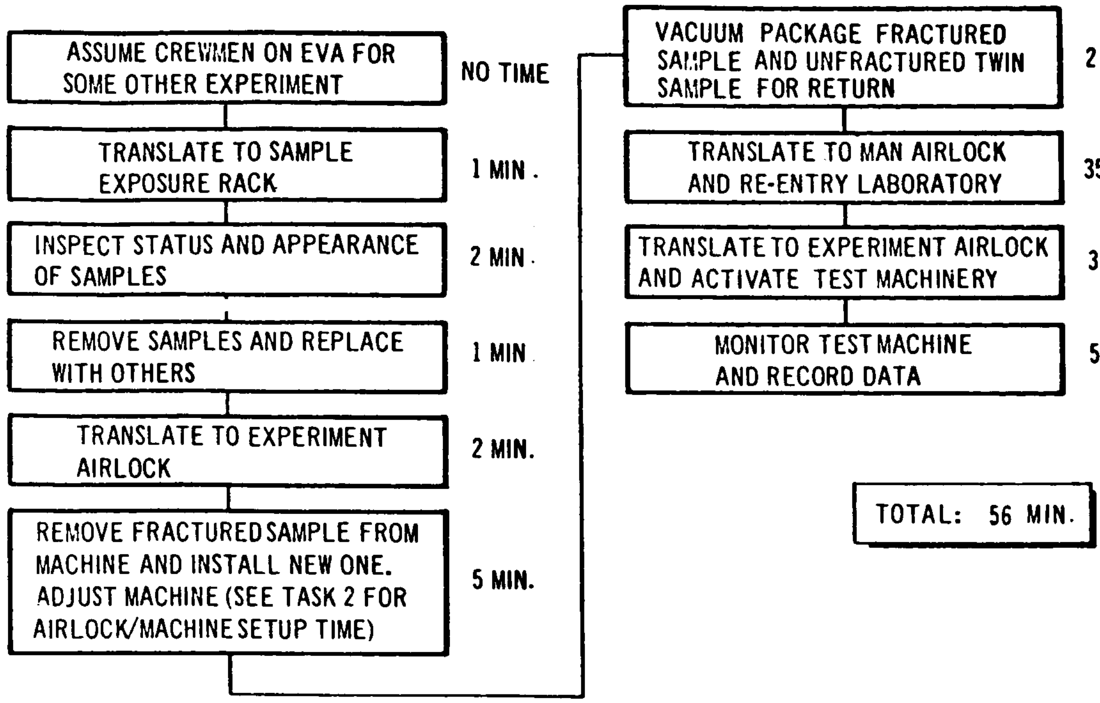


Figure 5- 30 . Fatigue Tests of Materials After Exposure to Space Environment – Part I, Task 1

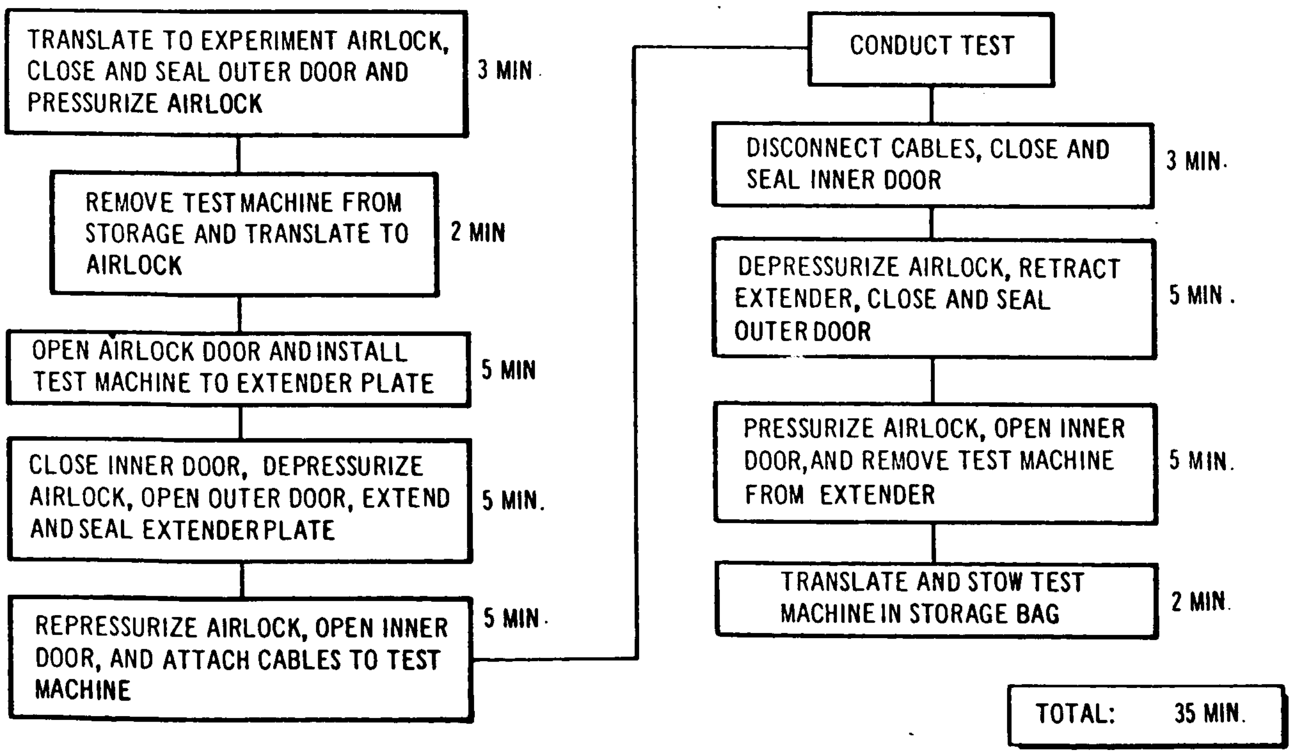


Figure 5- 31 . Fatigue Tests of Materials After Exposure to Space Environment – Part II, Task 2

For the 48-hour analysis, two crewmen will be required to perform these tasks. One will inspect and remove samples extravehicularly and one will standby in the airlock.

5.2.11 Ionizing Radiation Measurements (Data Bank Experiment No. IA-11)

Radiation measurements will be taken both inside and outside the spacecraft so that the two measurements can be correlated. Initially, the crew will take ionizing radiation measurements at a frequency of ten 2-min. periods/orbit for both inside and outside sensors. After about 30 days have elapsed, the sampling frequency will be reduced to one 2-min. period/orbit, or as required to ensure crew safety if regions of unusually high radiation are identified. For periods of abnormally high radiation (an average of 1/month is assumed), 30 min. of continuous data will be taken in a leg of the orbit for 6 to 10 consecutive orbits, and outside sensing (SRT) will be required.

There are essentially two parts to the experiment. Figure 5-32 shows the three tasks involving internal operations. Task 1 concerns the evaluation of film dosimeters worn by each crewman. Although the processor is automatic, the crewman must be skilled in handling film and equipment and must be capable of interpreting results from a film reader. This task will consume 30 min. of crew time. The second task is to record electrometer readings and to recharge the electrometer worn by each crewman. This task will require about 16.5 min. The third task is the monitoring the ionization and scintillation equipment at the scientific console. This task will require only 4 min./day. These tasks can be performed by a general technician, but a phototechnician/cartographer would be preferable for Task 1.

The extravehicular tasks are shown in Part II of Figure 5-33. They involve the external installation of the SRT and the gathering of data from the space environment. These tasks are performed from within the airlock to void the need for EVA. These tasks require one technician for approximately 1 hour.

TASK 1

OBTAIN FILM DOSIMETERS FROM ALL CREW MEMBERS	5 MIN.
OBTAIN FILM FROM RADIATION FREE STORAGE	2 MIN.
REPLACE FILM IN BADGES AND DISTRIBUTE TO CREWMEN	5 MIN.
SET UP FILM IN PROCESSOR AND START PROCESSOR	5 MIN
MONITOR FILM PROCESSOR	1 MIN.
REMOVE FILM FROM PROCESSOR AND INSTALL IN FILM READER	1 MIN
EVALUATE FILM AND RECORD RESULTS	10 MIN
STORE FILM FOR EARTH RETURN	1 MIN.
TOTAL:	30 MIN.

TASK 2

TURN ON ELECTROMETER RECHARGER	0.5 MIN
OBTAIN ELECTROMETER FROM EACH CREWMAN	5 MIN
RECORD ELECTROMETER READING	3 MIN
RECHARGE EACH ELECTROMETER	3 MIN.
TURN OFF ELECTROMETER AND DISTRIBUTE ELECTROMETER TO EACH CREWMAN	5 MIN
TOTAL:	16.5 MIN

TASK 3

TRANSLATE TO SCIENTIFIC CONSOLE	1 MIN
MONITOR IONIZATION AND SCINTILLATION EQUIPMENT	2 MIN.
SPOT CHECK DATA AND RECORDINGS	1 MIN
TOTAL:	4 MIN

Figure 5-32. Ionizing Radiation Measurements – Part I

TASK 4

DEPRESSURIZE EXPERIMENT AIRLOCK	0.5 MIN.
OPEN AIRLOCK OUTER DOOR	0.5 MIN.
MANEUVER BOOM TO AIRLOCK POSITION AND SEAL	1.5 MIN.
PRESSURIZE AIRLOCK	1 MIN.
OBTAIN SRT FROM STORAGE	1 MIN.
OPEN AIRLOCK DOOR AND INSTALL ON BOOM	5 MIN.
TURN ON SRT EQUIPMENT, CHECK OUT AND CALIBRATE	10 MIN.
CLOSE AIRLOCK DOOR AND DEPRESSURIZE	5 MIN.
RELEASE BOOM HEAD FROM AIRLOCK AND MANEUVER TO POSITION FOR RADIATION MEASUREMENTS	1 MIN.
MONITOR DATA AND RECORDING APPARATUS (TAPE) AND POSITIONAL INFORMATION FROM COMPUTER	20 MIN.
MANEUVER BOOM TO AIRLOCK AND SEAL; TURN OFF EQUIPMENT	1.5 MIN.
PRESSURIZE AIRLOCK	1 MIN.
OPEN AIRLOCK DOOR AND REMOVE SRT	5 MIN.
DEPOSIT SRT IN STORAGE	1 MIN.
TOTAL:	54 MIN.

Figure 5-33. Ionizing Radiation Measurements – Part II

5.2.12 Ventilation of Respired Gases in Manned Space Enclosures (Data Bank Experiment No. IIID-17)

The principal objective of this experiment is to help determine the minimum atmospheric requirements for human and animal support in the spacecraft environment. The results would be used in conjunction with metabolic data obtained from related experiments on biological energy management. These data would also help establish power requirements for both normal and emergency conditions.

A technician would spend about 31 min./day taking chromotograph readings, interpreting readings, and recording observations. These tasks, shown in Figure 5-34, would be performed at the scientific experiment console.

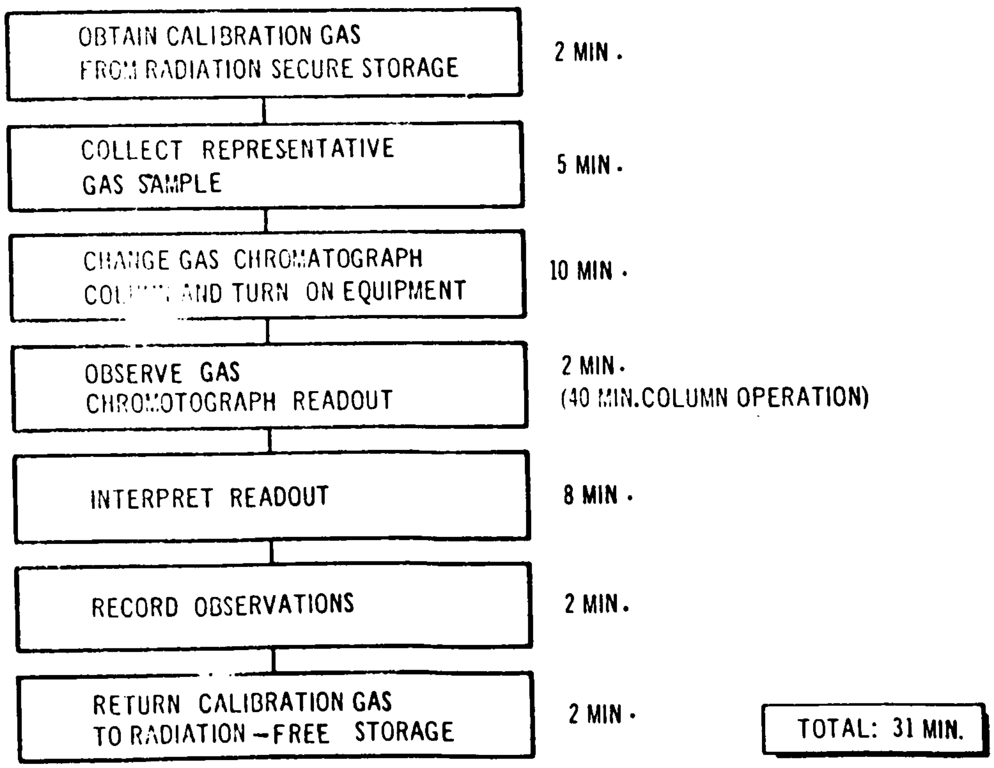


Figure 5-34. Ventilation of Respired Gases in Manned Space Enclosures

5.2.13 Evaluation of Life-Support System to Detect Microbiological and Chemical Contaminants (Data Bank Experiment No. IIID-16)

The laboratory's potable water and purified air supplies will be continuously sampled for bacterial contamination. These systems will be provided with bypass lines with micropore filters in the outlet streams, through which metered volumes will pass, and any contaminants present will be collected on the filters. These will be replaced daily with sterile filters.

The crew's first task, shown in Figure 5-35, is to change the filters in both the water and the air supply lines. They will then place the contaminated filters on sterile agar plates in the biological/liquid experiment compartment. Next the filters will be covered and incubated at 37°C for 24 hours. This task will occupy a biology technician for about 28 min. The second and third tasks are concerned with analyzing filter samples. The tasks are shown in Figure 5-36. Task 2 involves examining the filters under a microscope and recording the observation. This task can be accomplished in about 32 min. by one biological technician. The third task is to mix measured samples of water and food with freeze-dried growth material and to store these samples. This task will also be accomplished by a biology technician and can be completed in 14 min.

For the 48-hour study, one crewman will perform Tasks 1 and 2, spending 60 min. /day in the operation.

TASK 1

REMOVE STERILE MICROPORE FILTERS FROM STORAGE	4 MIN.
REMOVE CONTAMINATED FILTERS FROM WATER AND AIR-SUPPLY LINES	5 MIN.
REPLACE CONTAMINATED FILTERS WITH STERILE FILTERS	7 MIN.
TRANSFER FILTERS TO BIOLOGICAL/ LIQUID EXPERIMENT COMPARTMENT	3 MIN.
PLACE FILTERS ON STERILE AGAR PLATE	5 MIN.
COVER FILTERS	3 MIN.
TURN ON INCUBATOR	1 MIN.

TOTAL: 28 MIN.

Figure 5-35. Evaluation of Life-Support System to Detect Microbiological and Chemical Contaminants – Part I

TASK 2

REMOVE FILTER SAMPLES FROM INCUBATOR	5 MIN.
REMOVE COVER FROM FILTERS	3 MIN.
PLACE FILTERS UNDER MICROSCOPE	2 MIN.
EXAMINE FILTERS	15 MIN.
RECORD OBSERVATIONS	7 MIN.

TOTAL: 32 MIN.

TASK 3

OBTAIN FREEZE-DRIED GROWTH FOOD FROM STORAGE	2 MIN.
TRANSLATE TO BIOLOGICAL TEST ROOM	1 MIN.
OBTAIN MEASURED SAMPLE OF WATER AND MIX WITH DRIED GROWTH MATERIAL	5 MIN.
OBTAIN STERILIZED AGAR PLATES FROM STORAGE AND APPLY GROWTH MATERIAL AND STORE	2 MIN.
CLEAN USED PLATES AND DEPOSIT IN STERILIZER	2 MIN.
TURN ON STERILIZER AND CHECK OPERATION	1 MIN.
DEPOSIT STERILIZED AGAR PLATES IN STORAGE	1 MIN.

TOTAL: 14 MIN.

Figure 5-36. Evaluation of Life-Support System to Detect Microbiological and Chemical Contaminants – Part II

5.2.14 Evaluation of Behavioral Responses in the Orbital Environment, Part I (Data Bank Experiment No. IIIA-5)

The first part of the behavioral response evaluation will be the application of a set of standard behavioral measurements to each crew member. The purpose will be to evaluate crew performance as it relates to length of stay in the orbital environment.

Crew procedures are outlined in Figure 5-37. They will require 36 min. /man/test. Each crewman will serve as a subject once each week. During the 48-hour period, it is assumed that two of the six crewmen will perform this test.

Although there are a number of different subtests, the general procedure format will be as follows: the subject is seated at the biomedical-behavioral experiment console. He positions a rotary selector switch to identify himself and the particular task to be evaluated. He then sets up a particular test by inserting a film cartridge, adjusting the behavioral measurement

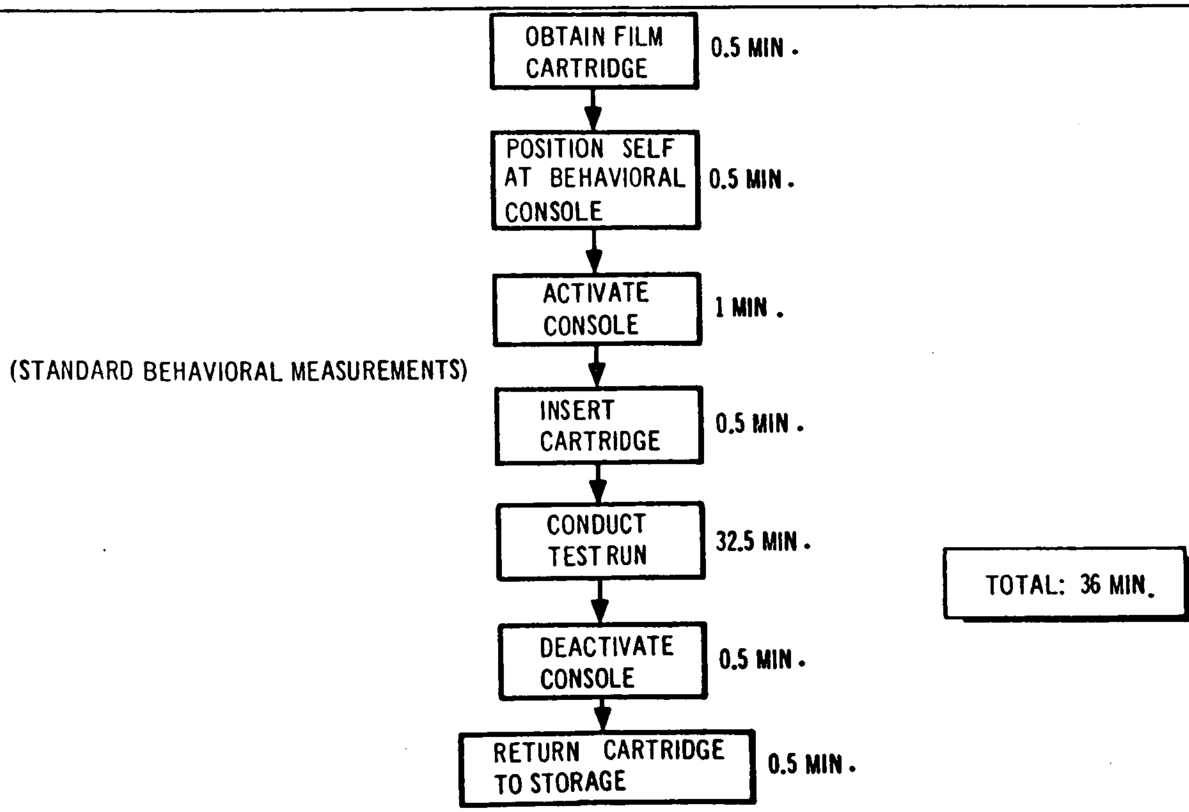


Figure 5-37. Evaluation of Behavioral Responses in the Orbital Environment – Part I

chair, attaching a hood to the CRT display, or performing required duties to adapt the console to a specified testing procedure. He then activates the test run by pushing the ready button, rotating the chair, or donning earphones, as required. The subject then responds to whatever stimulus is presented. The results are recorded automatically, stored, and later transmitted to the ground.

5.2.15 Evaluation of Behavioral Responses in the Orbital Environment, Part II (Journal Recording) (Data Bank Experiment No. IIIA-6)

This part of the behavioral response measurements utilizes the journal recording technique. Each crewman will record on tape a diary of his daily activities. He will be advised to record certain standard topics and also any occurrences and opinions he wishes. The tapes will be reviewed only by authorized ground personnel. Each crewman will spend an average of 15 min./day/test. These steps are outlined in Figure 5-38. The subject will take a portable tape recorder to his sleeping quarters and perform the test there in privacy.

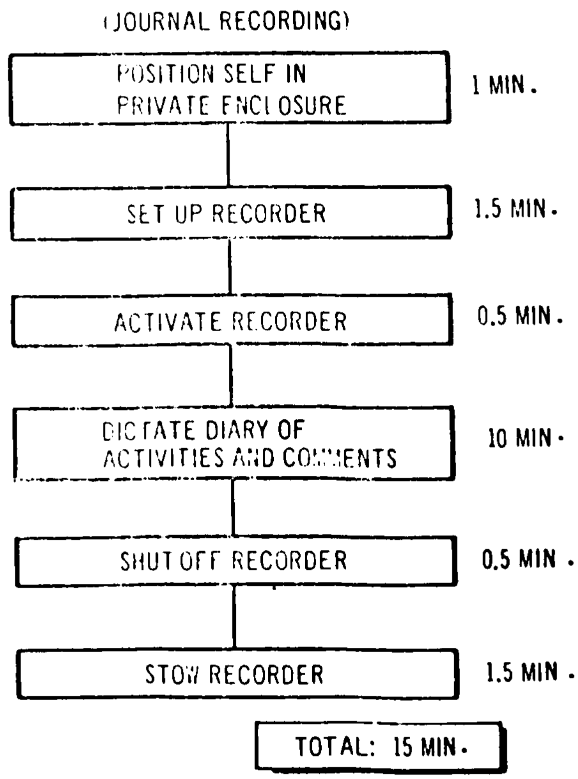


Figure 5-38. Evaluation of Behavioral Responses in the Orbital Environment – Part II

5.2.16 Retention of Skills Learned in the Orbital Environment (Data Bank Experiment No. IIIA-8)

Tracking and dexterity tests will be used under controlled conditions to measure the degree to which a motor skill learned under the conditions of weightlessness would be retained after return to Earth.

The general approach would be to test all subjects with both the tracking and dexterity measure prior to the orbital phase of the mission; within a few days after returning to Earth; and again 3 months later. While on board the laboratory, however, only one-half the subjects would practice the tracking task, and one-half the dexterity task. Records of performance would be maintained, and a comparative analysis made.

Performance of the test on board the laboratory will require a subject and an observer for 30 min./test. Each subject would practice every day for 10 days and then cease practicing for a 50-day period. Practice would continue in this fashion throughout the crewman's tour-of-duty.

The procedures to be followed by both subject and observer are shown in Figure 5-39. For the tracking test, the subject will be seated at the behavioral console. The tracking apparatus will consist of two handles connected electrically to a pointer mechanism which will be represented, along with a target, on a CRT. The subject will track the target, which has been programmed to follow a path that appears random to the subject. The observer will record error scores or time on target.

For the dexterity test, the subject will be provided with two containers and some small, odd-shaped pegs. He will transfer the pegs from one container to the other. Errors will be recorded and maintained for future analysis.

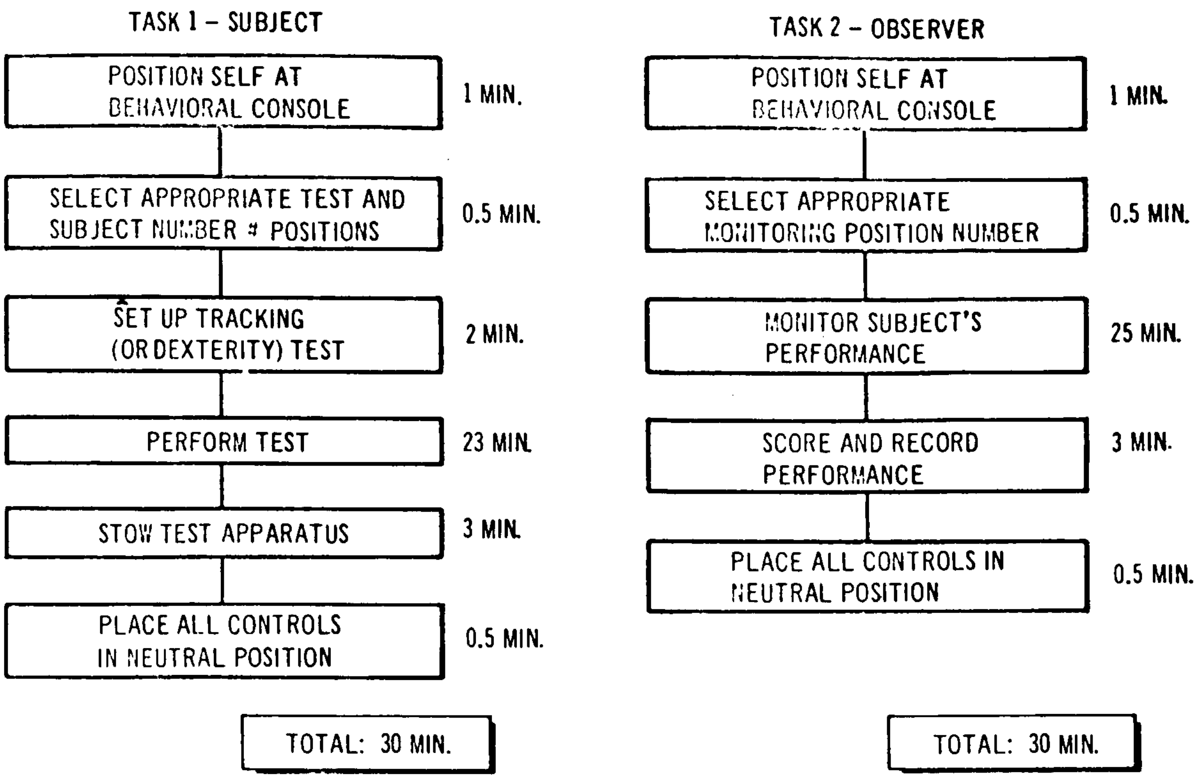


Figure 5-39. Retention of Skills Learned in the Orbital Environment

5.2.17 Crew Performance in Orbital and Re-Entry Operations (Data Bank Experiment No. IIIA-7)

The purpose of this experiment is to evaluate the ability of man to retain skills learned on the ground in the orbital environment. About once per month, each crewman will perform a simulated return to Earth. The simulation apparatus will be located in the biomedical-behavioral test station. The subject, seated at the console, will activate simulated controls and observe simulated displays associated with the logistics vehicle. The subject will follow programmed routine and abnormal procedures from beginning of checkout to landing. Error scores will be recorded, stored, and shown to the subject at the end of the session. These data will be transferred to the ground at some convenient time.

Other aspects of crew performance to be evaluated will include mass handling, donning space suit, voice communication, and television interview (if available). Performance ratings by the Flight Commander, and actual re-entry performance will be quantitatively rated.

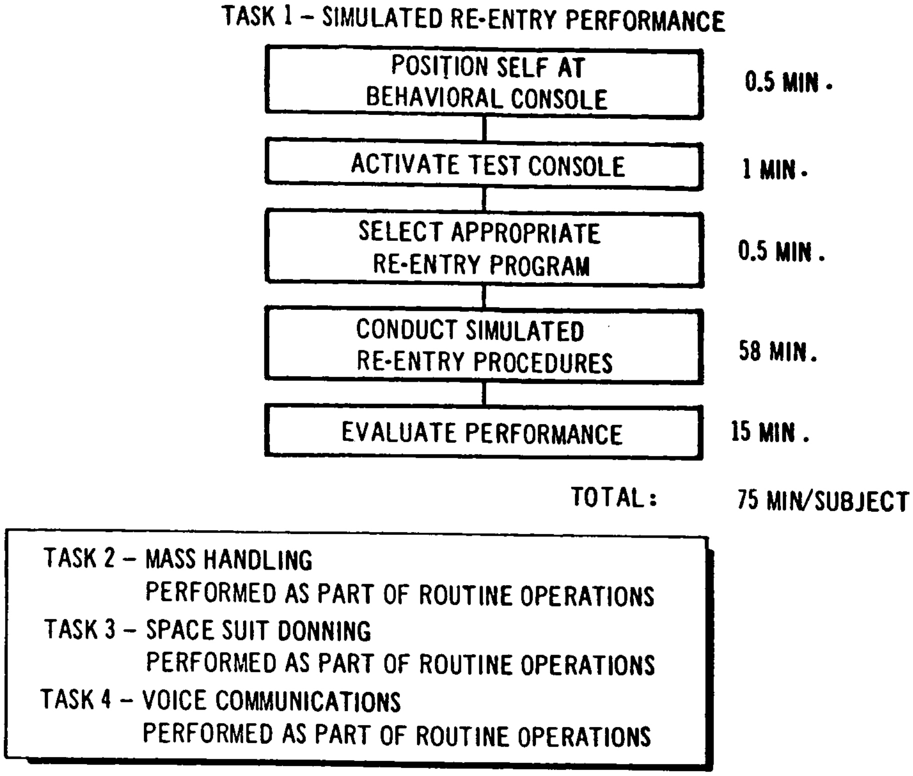


Figure 5-40. Crew Performance in Orbital and Re-entry Operations

All crewmen will participate in these tests, spending about 1.25 hour/man/test/30 days. All tests, except simulated re-entry, will be performed as a part of routine operations. The tasks are shown in Figure 5-40.

5.2.18 Force-Producing Capabilities of Operators in Zero g (Data Bank Experiment No. IIIA-4)

Quantitative data will be gathered regarding man's capability to perform various manual tasks in the orbital environment. Oxygen consumption will also be evaluated during the performance of the tests.

Each crewman periodically will perform various manual tasks in order to evaluate force-producing capabilities with a variety of tools and equipment. The tasks will be performed in space suits (both pressurized and unpressurized) and in shirt-sleeve conditions.

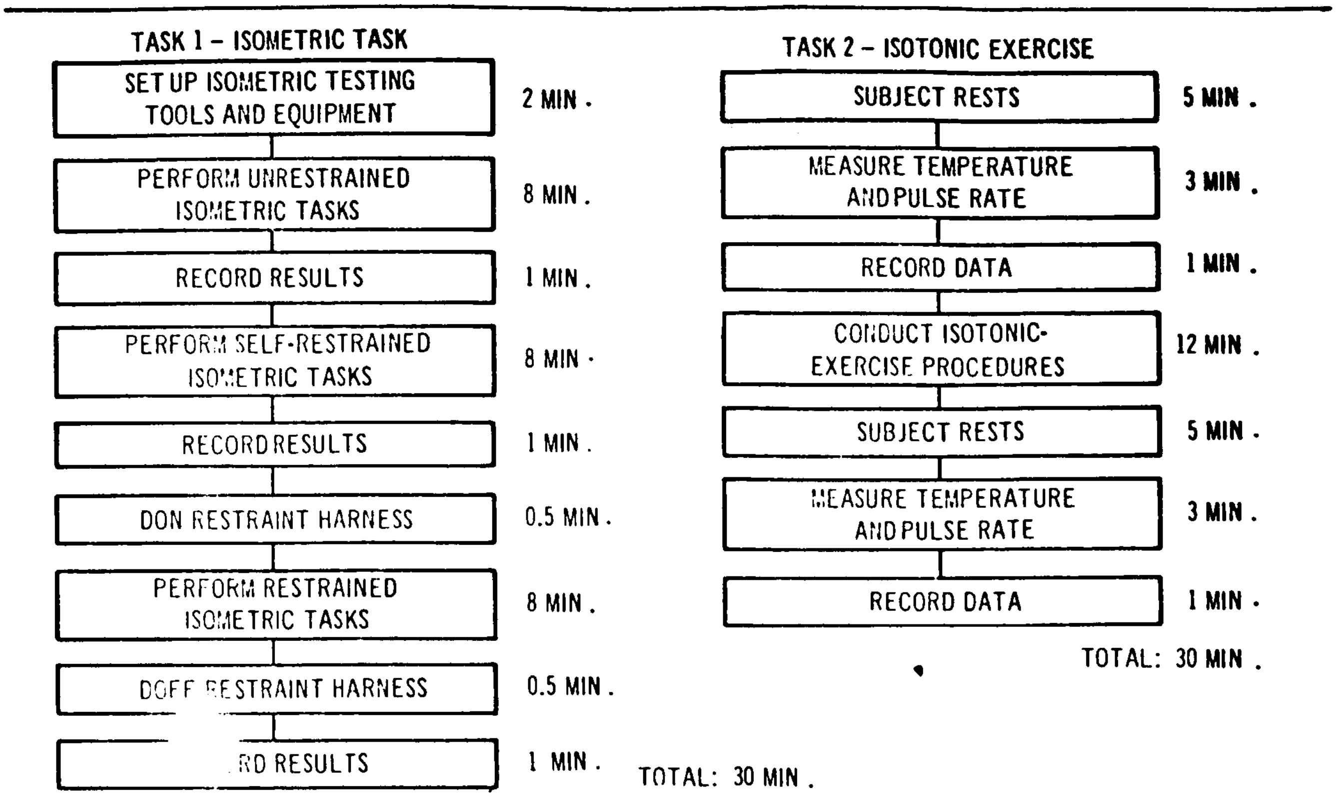


Figure 5-41. Force-Producing Capabilities of Operators in Zero-G

The protocol will generally call for donning appropriate clothing, setting up equipment and tools, performing tasks, and recording of elapsed times, force readings, etc. All crewmen will participate in the tests individually. The tests require 0.5 hour/man/test/6 days. There are essentially two tasks, as shown in Figure 5-41. One set of procedures is for isometric testing (both restrained and unrestrained) and one is for isotonic measurements.

5.3 TIME-LINE ANALYSIS

After each operational and experimental task to be accomplished by the flight crew was established, a time-line schedule and analysis of all crew activities was prepared to determine the adequacy of the baseline crew for accomplishing the assigned workload.

In preparing the schedule, the basic ground rules for scheduling defined in Phase IIa were reviewed and amended as required. This resulted in the formulation the following considerations in determining the priority for scheduling crew activities:

1. General
   - A. Target opportunities.
   - B. Communications opportunities.
   - C. Eight-hour sleep period.
   - D. One man available for station management.
   - E. Four-hour work cycle.
   - F. Personal hygiene and eating immediately following sleep.
2. Specific
   - A. Minimize cross-skill requirements.
   - B. Assign specialty experiments to one man.
   - C. Minimize number of men assigned to station operations and maintenance.
   - D. Life scientist to monitor biomedical-behavioral measures.

With these guidelines established, the first step in the construction of the time line was to schedule all orbit-dependent tasks. These tasks include the target opportunities for the four oceanography experiments, the SCS operations required to precede these measurements, and communications opportunities. Second, all daily required functions such as personal maintenance, biomedical monitoring, and physical fitness were scheduled. Last, all remaining functions, which, in general, are not time dependent, were scheduled.

With the crew workload requirements defined in considerable detail, it was possible to schedule all crew activities on a minute-by-minute basis. A preliminary time line was first prepared in an attempt to assign all these tasks to the baseline crew (that is, three men with engineering skills and three men who are experiment specialists, one each in medicine, life sciences, and physical sciences). Quickly, it became evident that there was more need for another physical scientist than for a medical specialist.

With this change to the baseline crew composition accomplished, the tasks were easily scheduled. The resulting time-line schedule is contained in a pocket attached to the rear cover of this document.

As can be seen, each activity is plotted to the nearest minute. Allowance has been made for the crew to transfer from one station or compartment to another before beginning the next task. For those station-to-station transfers within a single experiment, for example Radar 252 (about the 15th hour), an allotment was also made and is included in the time estimate for that task.

The flight crew work primarily in two shifts, that is, three sleep while three are on duty. Then there are periods of time during each day when the entire crew is on duty. At the end of the second day, the entire crew are resting together.

Tasks were assigned whenever possible to individuals in accordance with the skill assignments associated with the baseline crew composition. Because the experiments chosen for the 48-hour study contained four oceanographic experiments, which in most cases required simultaneous operation of equipment, primary responsibility for each of these experiments was assigned to one crewman.

The photography experiment was assigned to Experiment Specialist No. 1; microwave was assigned to the Operations Engineer; IR was assigned to the Flight Commander; radar was assigned to the Deputy Flight Commander. Similarly, Experiment Specialist No. 3, who is trained in the life sciences, is responsible for the biomedical, behavioral, and biological functions. The meaning of these assignments, with regard to scheduling, is that these individuals would perform the required tasks whenever they were available for duty. In this manner, cross-skill training could be minimized.

During the scheduling process, it was necessary occasionally to deviate from the scheduling ground rules and to utilize personnel in other than their assigned skill area. For example, it was necessary to interrupt a sleep period of the Flight Commander in order to make someone available for station management duties while three crewmen were engaged in extravehicular activities. Also, during this same period, the 4-hour work period was exceeded by 1 hour so that the EVA could be completed without interruption.

Because of the unavailability of preferred personnel, it was necessary to transfer those functions to others available for duty; for example, when the preferred crewman, the Flight Commander was asleep, the Deputy Flight Commander conducted the IR experiment.

It was necessary to utilize five of the six crewmen to accomplish the communications tasks during the 48-hour period. This results because the communication tasks occur frequently and are mandatory during a pass over the ground station. Similarly, four of the six crewmen are involved in photography tasks which range from data gathering to film processing to analyzing. These deviations are not only necessary, but they are also realistic for they allow accomplishment of mission goals without excessively stressing the capabilities of the individual or of the crew. It is not unreasonable to assume that a life scientist can easily be cross-trained in the operation of photo-processing equipment or communications equipment, or that an individual, on occasion, not only will, but can, work more than 4 hours without a rest period and without serious consequences.

Presented in Tables 5-4 and 5-5 are summaries of the flight crew's time requirements. Table 5-4 shows the amount of time in minutes each day that each crewman spends on any task. Table 5-5 presents these totals again along with the percentage of each crewman's time spent in various activities. From these tabular presentations, it is possible to construct an accurate image of each member of the flight crew, a brief description of which is given below.

Table 5-4

48-HOUR CREW-TIME REQUIREMENTS

	1 (PS)		2 (OE)		3 (F/C)		4 (D/C)		5 (PS)		6 (LS)		TOTAL (144 Man-Hr/Day)	
	1	2	1	2	1	2	1	2	1	2	1	2	Day 1	Day 2
Sleep	480	480	480	480	480	480	480	480	480	480	480	480	48.00	48.00
Eat	120	120	118	120	116	120	120	120	120	120	120	120	11.90	12.00
Personal hygiene	50	50	50	50	75	50	50	50	50	50	50	50	5.42	5.00
Rest	90	90	90	90	90	90	90	90	90	90	90	90	9.00	9.00
Biomedical – subject	40	40	40	40	40	40	40	40	40	40	40	40	4.00	4.00
Biomedical – observer	--	--	--	--	--	--	--	--	40	40	200	200	4.00	4.00
Physical fitness	30	30	30	30	30	30	30	30	30	30	30	30	3.00	3.00
Centrifuge – subject	45	--	45	--	--	--	--	45	--	45	--	--	1.50	1.50
Centrifuge – observer	--	--	--	--	--	--	--	--	--	--	45	45	0.75	0.75
Operations – SCS	--	-*	--	--	50	40	20	30	--	--	--	--	1.17	1.17
– EC/LS	--	--	--	--	23	23	--	--	--	--	--	--	0.23	0.23
– Communications	--	57	34	--	37	68	18	--	17	--	--	--	1.77	2.07
– Power	--	--	--	--	--	45	--	--	--	--	--	--	0	0.75
– Propulsion	--	--	25	20	--	5	5	5	--	--	--	--	0.50	0.50
Maintenance – SCS	--	--	--	--	--	--	--	--	--	--	--	--	0	0
– EC/LS	--	--	--	--	--	9	--	--	--	--	--	--	0	9
– Communications	--	--	40	80	--	--	--	--	--	--	--	--	0.67	1.33
– Power	--	--	--	--	--	30	--	--	--	--	--	--	0	0.50
– Propulsion	--	--	--	--	--	--	--	--	--	--	--	--	0	0
Engineering experiment – 252	--	--	--	172	--	--	395	--	300	--	279	--	16.23	2.87
– 255	175	84	--	--	--	--	--	258	118	330	--	178	4.88	14.17
– 257	--	--	--	--	108	70	20	23	--	--	--	--	2.13	1.57
– 256	--	--	102	--	--	--	--	--	--	--	--	--	1.70	0
– IA-1	15	--	--	--	--	--	--	--	--	--	--	--	0.25	0
– IA-11	--	60	--	--	--	--	--	--	--	--	--	--	0	1.00
– IB-23	15	15	--	--	--	--	--	--	--	--	--	--	0.25	0.25
– IC-15	12	12	--	--	--	--	--	--	--	--	--	--	0.20	0.20
– IIC-1	--	--	80	80	--	--	--	--	--	--	--	--	1.33	1.33
– IIIB-3	--	--	--	--	--	--	--	151	--	122	--	--	0	4.55
– IIIB-6	6	--	--	--	--	--	--	--	--	--	--	--	0.10	0
– IIID-16	--	--	--	--	--	--	--	--	--	--	60	60	1.00	1.00
– IIID-17	--	--	--	--	--	--	--	--	--	--	--	31	0	0.52
Behavioral experiment – IIIA-4	--	30	--	--	30	--	--	--	--	--	--	--	0.50	0.50
– IIIA-5	36	--	--	--	36	--	--	--	--	--	--	--	1.20	0
– IIIA-6	15	15	15	15	15	15	15	15	15	15	15	15	1.50	1.50
– IIIA-7	--	75	75	--	--	--	--	--	--	--	--	--	1.25	1.25
– IIIA-8	--	--	--	30	--	--	--	--	30	--	--	--	0.50	0.50
– IIIA-8 (O*)	--	--	--	--	--	--	30	--	--	--	--	30	0.50	0.50
Transfer	28	31	33	33	35	35	31	20	22	21	26	22	2.92	2.70
Unassigned and contingency	283	251	183	200	267	290	96	83	88	57	5	49	15.55	15.70
Total = 1,440 Min./Man/Day														

*Observer

Table 5-5

SUMMARY OF FLIGHT CREW-TIME REQUIREMENTS

Crewman	ACTIVITY OR FUNCTION															
	Operations		Maintenance		Biomedical Monitoring		Engineering Experiments		Behavioral Experiments		Personal Maintenance		Transfer		Contingency/ Unassigned	
	Min.	%	Min.	%	Min.	%	Min.	%	Min.	%	Min.	%	Min.	%	Min.	%
Flight Commander	291	9.8	39	1.4	140	4.8	178	6.2	96	3.3	1,501	52.1	70	2.4	557	19.6
Deputy Flight Commander	78	2.7	none		185	6.4	847	29.4	60	2.1	1,440	50.0	51	1.8	179	6.2
Operations Engineer	79	2.7	120	4.2	185	6.4	434	15.1	135	4.7	1,478	51.3	66	2.3	383	13.3
Experiment Specialist No. 1 (Physical sciences)	57	2.0	none		185	6.4	394	13.7	171	6.0	1,480	51.3	59	2.1	434	15.1
Experiment Specialist No. 2 (Physical sciences)	17	0.6	none		265	9.2	870	30.2	60	2.1	1,440	50.0	43	1.5	145	5.0
Experiment Specialist No. 3 (Life sciences)	none		none		630	22.0	608	21.1	60	2.1	1,440	50.0	48	1.7	54	2.0
TOTALS	522		159		1,590		3,331		582		8,779		337		1,752	
Percentage of total man-hours (17,280)	3		0.9		9		19.2		3.4		50.8		2		10.2	

NOTE: Figures in minute column are totals for 48-hour period. Percentage figures are based on total hours available for each crewman.

*Include physical fitness and centrifugation.

The Flight Commander performs the majority of station operation functions (9.8% of his time compared to 8% for the rest of the crew). He is trained to conduct the IR experiment and does so whenever he is available, that is, on duty. This is the only engineering/scientific experiment in which he is involved. He and all other crew members participate daily as subjects in the behavioral experiments. The Flight Commander's schedule includes the most unassigned time (19.6%), which makes him available to assist with and/or to perform the decision functions, as required. It is his sleep that is interrupted for the purpose of standing by while three other crewmen are involved in EVA.

The Deputy Flight Commander is assigned many similar responsibilities, as he is the leader of the second shift of three (three on duty while three sleep). He has some station operations duties, but, unlike the Flight Commander, he is involved in the experiment program (29.4% for engineering experiments). He has prime responsibility for the radar experiment, which requires more crew time than the other three oceanographic experiments, and leads the EVA team that installs the antenna on the outside of the laboratory. He is also involved in performing the IR experiments when the Flight Commander is unavailable and participates in the processing of film. He serves as a centrifuge subject.

The Operations Engineer will perform the majority of the station maintenance tasks, since this is his primary responsibility. He will also complete a portion of routine station operations tasks. He is responsible for the microwave experiment, and his schedule is such that he, alone, performs this task during the 48-hour period. He substitutes for the Deputy Flight Commander when he is unavailable to perform the radar experiment. He also conducts the communications experiment. In addition, he will serve as a centrifuge subject. He is assigned a variety of relatively short-term tasks throughout the day. Many of these are followed by short periods of unassigned time, and, as a result, he has a large amount of unassigned time. This is a realistic situation, since, in practice, his station operations and, particularly, maintenance tasks will require more hours to perform on certain days.

Experiment Specialist No. 1, who is skilled in the physical sciences, will assist in certain routine station operations tasks. He was not assigned any operational maintenance tasks. His experiment time will be spent in engineering measurements, behavioral studies (primarily as a subject and with more time, 6%, than other crew members), and as a centrifuge subject. His primary assignment is that of photography expert, which he shares with Experiment Specialist No. 2. He will perform the data gathering tasks whenever he is available. Although several crew members are involved in photography tasks, Experiment Specialist No. 1 is the experiment leader.

Experiment Specialist No. 1 participates in more experiments (11 of 18) than any other crewman. Most of these tasks are of short duration and, hence, are followed by many short periods of unassigned time to permit him some flexibility in completing these tasks. As a result, he has the second highest amount of unassigned time (15.1%) next to the Flight Commanders.

Experiment Specialist No. 2, who is also skilled in the physical sciences, will spend the bulk of his day conducting engineering studies (30.2%). He will also participate in station operation duties, but not in maintenance tasks. He shares responsibility for the photography experiment with Experiment Specialist No. 1. He is involved in data gathering and also performs the primary tasks of photo interpretation and analysis. It was possible to schedule him with only a minimum amount of unassigned time.

Experiment Specialist No. 3, who is trained in the life sciences (especially biomedicine and biology) will concentrate on the monitoring of subjects (22%) and in assisting with the scientific measurement engineering (21.1%). He was, as planned, excluded from operations and maintenance tasks. He has the smallest allocation of unassigned time because it was possible to schedule his available time efficiently.

In summary, the Flight Commander, Deputy Flight Commander, and Operations Engineer will accomplish about 90% of all station operations and maintenance tasks, and they will perform 45% of the experiment effort. The two experiment specialists, trained in the physical sciences, will perform only about 11% of the station operations and maintenance tasks, but they will be responsible for about 55% of the experiment program. The experiment specialist trained in the life sciences will not perform any station operation or maintenance tasks. He will contribute 20% of the engineering and behavioral experiment workload. Also, he will be responsible for nearly 40% of the time spent in biomedical monitoring, physical fitness, and centrifugation.

Table 5-6 contains the summary of skill requirements for the flight crew. Figure 5-42 presents the skill requirements as a percent of total time spent performing experiments. As can be seen when viewing both tables, electromechanical and photography-skill requirements are predominant. All six crew members must be trained in the electromechanical skill to the technician level. Four of the six crew members must have photography training; two are required only for processing of film.

A description of the three major skill categories is provided in Table 5-7. The chart shows that the technicians from the physical sciences field will be selected from three subfields, namely, photography/cartography, optics,

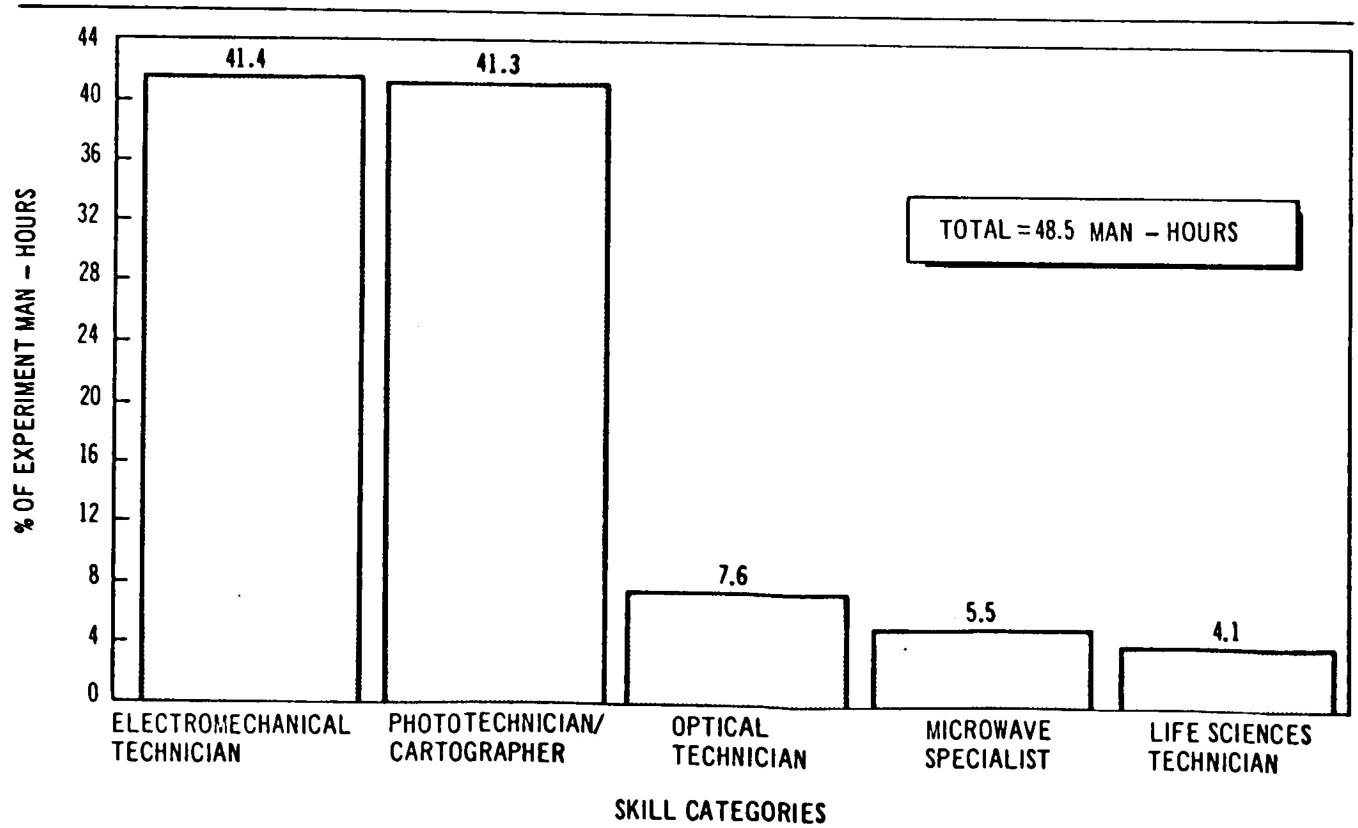


Figure 5-42. Experiment Skill Summary

Table 5-6

FLIGHT CREW EXPERIMENT SKILL SUMMARY

Crewman	Skill	Level
Flight Commander	Electromechanical	Technician
	Optical	Technician
Deputy Flight Commander	Electromechanical	Technician
	Photography	Technician
Operations Engineer	Electromechanical	Technician
	Electronics	Microwave specialist
Experiment Specialist No. 1	Electromechanical	Technician
	Photography	Technician/interpreter
Experiment Specialist No. 2	Electromechanical	Technician
	Photography	Technician/interpreter
Experiment Specialist No. 3	Biology	Technician
	Photography	Technician
	Electromechanical	Technician

Table 5-7

EXPERIMENT SKILL DESCRIPTIONS

Skill Category	Description
I. Electromechanical technician	Performs routine operations and maintenance tasks, including monitoring, checkout, fault isolation, and repair and replace tasks at the component level. Installs, operates, and maintains general-purpose experiment equipment and facilities. Will be thoroughly trained in extravehicular procedures. Has either an engineering degree or 3 to 5 years technical experience.
II. Physical sciences technician	
a. Photography technician/ cartographer	Installs, operates, and maintains photographic equipment and facilities; processes, analyzes, and interprets photographic data, including black-and-white and color film. Has 3 to 5 years technical experience.
b. Optical technician	Installs, operates, and maintains optical equipment and facilities, including IR sensing equipment. Collects and interprets data. Has 3 to 5 years technical experience.
c. Microwave specialist	Installs, operates, and maintains communications equipment, including radar and associated equipment; collects and evaluates data such as ionograms and noise maps. Has 3 to 5 years technical experience and is thoroughly trained in extravehicular procedures.
III. Life sciences technician	Operates and performs routine maintenance on experimental equipment and facilities. Gathers and interprets biomedical-behavioral data and performs biology and chemistry experiments. Is thoroughly trained in monitoring extravehicular crewmen.

and electromagnetic waves and electron physics (specifically, microwaves). In the 48-hour analysis, each of the four oceanographic experiments were assigned to one individual. Therefore, the Flight Commander's secondary skill will be that of an optical technician, and the Operations Engineer that of the microwave specialist. The life sciences technicians will have various combinations of training in the following subfields: anatomy, pharmacology, physiology, nutrition, medicine, microbiology, ecology, and biology. These skill categories and their descriptions were derived from the Specialties List for use with the National Register of Scientific and Technical Personnel.

The flight crew skill summary does not differ appreciably from the baseline requirements. Again, the only major change is the substitution of another physical sciences specialist for one with medical skills.

5.4 CONCLUSIONS

The following conclusions summarize the results of the flight crew analysis:

1. The baseline crew composition requirements (that is, crew size and skill mix) are satisfactory for laboratory operations and maintenance procedures, but they are not compatible with the experiment program. Namely, there is no need for both an M. D. and a life scientist during the 48-hour period. Instead, two physical scientists are required to perform the increased engineering experiment workload.
2. Cross-training of all crewmen in certain frequently performed tasks (for example, communications) is required. This training need be only to the skill level of a technician. Situations requiring analytical and diagnostic capabilities, such as failures, would still be handled by area specialists.
3. The dominant skills required are those of an electromechanical technician and a photography technician/cartographer. A large portion of the time required for both skills is for initial setup of equipment (for example, radar experiment). Additionally, the photography technician/cartographer will spend a great deal of time processing films.
4. The analysis indicated further that, for routine procedures such as those depicted during the 48-hour period, all six crewmen participate in all of the major crew functions except for operations and maintenance. In these instances, five crewmen will perform station operations tasks and only two crewmen are assigned routine maintenance procedures. The schedule was designed so that all crewman would participate in the engineering, biomedical, and

behavioral experiment programs. As with the baseline crew, over 50% of the crew's time is spent in personal maintenance activities, about 4% in performing station operations and maintenance tasks, about 32% in conducting experiments, and the remaining time is allocated to transfer, contingency, and unassigned.

5. The analysis also indicated that the time required for experimentation is heavily loaded with observer time. Extravehicular operations require a continuous monitor standing by in the airlock. All biomedical activities require an observer also, as do some behavioral measurements.

6. The predetermined schedule for orbital operations should contain a maximum number of meaningful tasks, thereby saturating available crew time to a high level of utilization. At the same time, it must remain flexible to permit the accomplishment of unscheduled activities without grossly affecting the planned objectives.

5.5 RECOMMENDED FOLLOW-ON STUDIES

The following areas of continued investigation are recommended for follow-on studies as a result of this flight crew analysis:

1. Techniques for automatically or semiautomatically monitoring biomedical subjects should be investigated. Currently, this task requires a significant amount of crew time and is difficult to schedule, since one crewman is assigned the task of observing all others at various times each day.

2. Techniques for performing personal hygiene functions should be investigated. Not only the procedures are important, but design details may require considerable lead time to complete.

3. The need for restraints, tools, and handling aids in a zero-g environment should be investigated. This would include such diverse situations as restraining food in a zero-g oven, transporting hand-held objects from one location to another while using hands to aid in locomotion, restraining experiment equipment and supplies, and performing most housekeeping tasks.

4. Methods for salvaging crew time during periods of emergency or peak workload should be explored for both operations and experimentation functions. The duration for which various personal maintenance functions can be suspended entirely without degrading performance should be investigated. Estimates should also be made of the time certain functions can be reduced and for what duration. The result would be a time savings program which could be initiated quickly by a properly trained crew. The schedule would vary for different crew members depending upon their particular stay time in orbit. Crewmen would be able to suspend or to reduce personal support functions to the maximum allowable during the earlier portions of their stay in orbit. Analysis should be made of the rate at which these times could be reduced.

5. Methods for conducting behavioral measurements of routine, emergency, and maintenance operations should be investigated. It is known that this suggestion is feasible and certainly desirable in order to increase crew time for useful work, but little is known about the techniques to be employed.

6. Finally, the techniques used to generate the 48-hour time line schedule were time consuming and laborious. However, at least this depth of analysis is required before an actual flight schedule can be established. The amount of time required to construct such a flight plan for an extended duration mission for the MORL is staggering, even though the plan can be formulated in segments. Furthermore, in-orbit adjustments of duty schedules necessitated by unscheduled events will also consume a significant portion of at least one crew member's time. Improved techniques for automatic scheduling of crew functions, therefore, should be investigated.

Section 6
EXPERIMENT INTEGRATION

The baseline internal and external configuration of the MORL (Figure 6-1) is defined in the Phase IIa Final Report, Volume XI, Laboratory Configuration and Interiors, SM-46082. The basic power generating system consists of solar cells and batteries. The laboratory's orientation for experiments is belly down; this means that experiment sensors requiring alignment to Earth vertical are located on the bottom side of the laboratory.

6.1 SUMMARY OF INSTALLATION/CONFIGURATION REQUIREMENTS

Summaries of the individual installation/configuration requirements for each experiment to be conducted during the 48-hour period are noted in Table 6-1 and Figures 6-2 through 6-16. Figures depicting equipment installation and packaging are merely schematic in nature and do not represent the recommended installation. Table 6-2 presents the general laboratory requirements when all experiments are considered.

6.2 CONFIGURATION ANALYSIS

The reasons that lead to the recommended changes to the baseline configuration are presented in the following paragraphs. These changes are the result of a detailed analysis of the 48-hour study.

6.2.1 Additional Provisions or Modifications

6.2.1.1 Hangar Deck Control Console

The internal facilities of the baseline configuration appear to be satisfactory with the exception that a new console and operator control panel is required in the hangar deck adjacent to the experimental airlock. Certain of the equipment operating in the airlock will require close control which can not

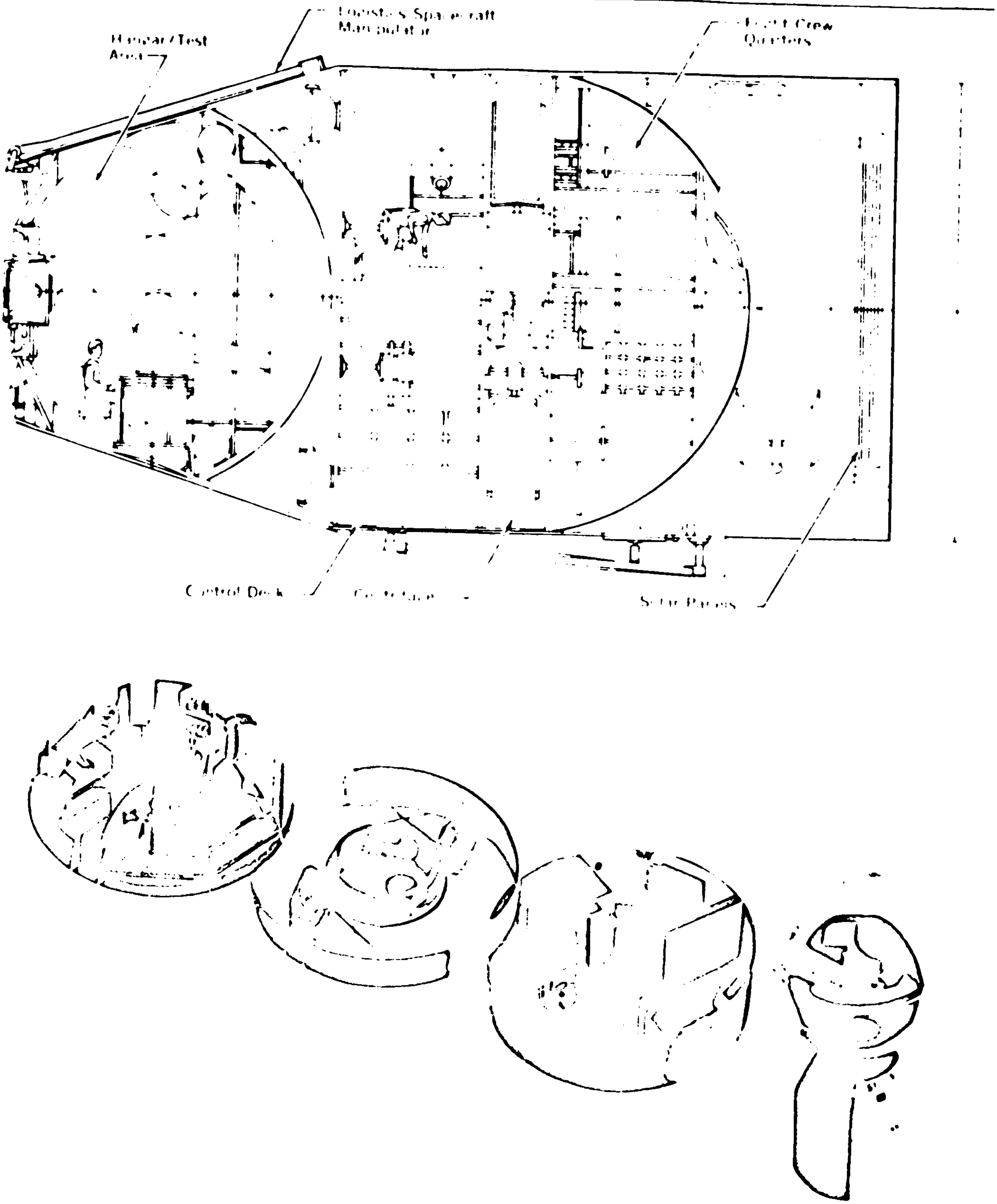


Figure 6-1. MORL Baseline

Table 6-1

EXPERIMENT INSTALLATION/CONFIGURATION REQUIREMENT SUMMARY (page 1 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirements	Remarks
A-1	Radar	1. Synchronizer (R100)	12x6x6	1. Internal location. 2. Cable lead length not critical. 3. Cold plate or equivalent cooling required (8 W).	1. See Figures 6-2 and 6-4.
		2. Console display and receiver (R110)	10x12x14	1. Internal location at a console. 2. Cable load length within 10 ft of transmitter. 3. Cold plate or equivalent cooling required (12 W). 4. Operator access for equipment control required during operation.	1. See Figures 6-2 and 6-3. 2. Console and operator control space is necessary. 3. Electrical connection to data management computer is necessary.
		3. Controller (antenna drive R120)	12x6x6	1. Internal location. 2. Cable lead length not critical. 3. Cold plate or equivalent cooling required (10 W).	1. See Figure 6-2.
		4. Data recorder (R130)	12x6x12	1. Internal location. 2. Cable lead length not critical. 3. Cold plate or equivalent cooling required (10 W). 4. Operator access to tape and controls necessary.	1. See Figure 6-2.
		5. Transmitter (R140)	12x8x12	1. Internal location. 2. Cable lead length and rf waveguide within 15 ft of antenna. 3. Pressure wall feed through required for cable and waveguide. 4. Antenna waveguide requires pressurization. 5. Cooling necessary (70 W).	1. See Figure 6-2.
		6. Power supply (R150)	12x6x12	1. Internal location. 2. Cable lead length not critical. 3. Cold plate cooling or equivalent necessary (60 W).	1. See Figure 6-2.
		7. Antenna (R160)	4.5-ft diam Hemisphere	1. External location. 2. Antenna axis must be aligned with the local earth vertical axis. 3. Antenna mounting base must be capable of alignment within $\pm 0.1^{\circ}$ of attitude reference system (ARS) in each orthogonal axis. 4. Antenna articulation envelope is a 4.5 ft diam hemisphere. 5. Antenna gimbal mount must enable $\pm 50^{\circ}$ azimuth and $\pm 30^{\circ}$ elevation antenna travel. 6. Cable and waveguide lead length within 15 ft of transmitter. 7. Pressure feedthrough required for antenna power leads and waveguide (2 required).	1. See Figure 6-2. 2. An airlock sized for two crewmen and equipment is necessary for antenna erection. 3. Antenna installation and alignment with attitude reference system requires use of manually operated optical equipment. This requires suitable windows and vision paths between ARS and the antenna.
A-2	Photography	1. Camera body (P101)	12x12x12	1. Items 1, 2, 3, 4, 5 and 6 assemble together to form a gimballed camera which is 46 in. long, 12 in. high, 12 in. wide (approximately).	1. See Figure 6-5 and 6-7.

Table 6-1 (page 2 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation Configuration Requirements	Remarks
		2. Photometer (P102) 3. Film pack (P103) 4. Lens and filter pack (P104) 5. Contrast plate (P105) 6. Gimbal (frame and drive (P106)	2x2x3 20x10x10 24x9x18 8x8x1/2 36-in. diam x12 in. H.	2. Camera assembly mounts into the experimental airlock 3. Camera gimbal mounting must enable alignment to the attitude reference system within 0.1° in each orthogonal axis. (Optical sighting and vernier adjustment preferable.) 4. Camera and gimbal require articulation to enable camera alignment ±10° from vertical axis (in any azimuth—a 20° cone). 5. Storage convenient to camera is required for interchangeable lens, filters, and other equipment (5 cu ft). 6. Storage (radiation secure) is necessary for unexposed film (0.5 cu ft).	2. A control console adjacent to the camera system is necessary. 3. Suitable lighting for camera operation is necessary. 4. Electrical connection to data management computer is necessary.
		7. Optical dome (P108)	9-in. radius hemisphere	1. Installs in airlock with nominal centerline of dome axis aligned with nominal camera centerline; camera centerline must be parallel to local Earth vertical. 2. Pressure seal at dome periphery is required. 3. The field of view, as measured from the dome, must be a 30° cone.	1. See Figure 6-5.
		8. Data input and mission monitor (P107)	10x12x4	1. Internal location convenient to airlock (preferable location in console adjacent to airlock). 2. Cable lead length to camera not critical. 3. Cold plate or equivalent cooling is necessary (10 W).	1. See Figure 6-6.
		9. Programmer (P109)	6x6x6	1. Same as Equipment Item 8.	
		10. Film processor, wet (9 in. by 9 in. film format)	36x12x12	1. Internal location in light proof area 2. Dark Room must have controlled atmosphere to control vapors and fumes for processing chemicals, spilled liquids, temperature and humidity control is also required. 3. Liquid handling apparatus and tanks for changing film processor is necessary. 4. Power for operating processor is necessary. 5. Processor cooling is required (300 W). 6. Film drying is required (500 W).	1. Work space surrounding processor for film spools, liquid and chemical exchange, and crew operations is necessary.
		11. Film projector	18x12x12	1. Internal location adjacent to film scanner. 2. Cooling for projection equipment (300 W).	1. Work space for operator is required 2. Projection equipment may use forced ventilation for cooling.
		12. Film scanner (optical to electronic)	12x12x12	1. Internal location adjacent to film projector.	

Table 6-1 (page 3 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirements	Remarks
A-3	Microwave radiometry, two frequency	1. Operator console and display (M100)	9x12x12	1. Internal location convenient to other equipment. 2. Cable lead length to other equipment not critical. 3. Cold plate or equivalent cooling required (10 W). 4. Operator access for equipment control during operation is required.	1. See Figure 6-9. 2. Work space, suitable lighting, etc. is necessary. 3. A console is desirable for access to data recording equipment and control panel equipment. 4. Storage for equipment during non-use periods is necessary (size = 4 cu ft--12 ft x 24 ft x 24 ft. 5. Interface to computer is necessary.
		2. Controller, antenna drive (M110)	12x6x12	1. Internal location convenient to other equipment. 2. Cable lead length is not critical.	
		3. Data recorder (M120)	12x6x12	1. Internal location convenient to other equipment. 2. Cable lead length not critical but should be reasonably short. 3. Cold plate cooling or equivalent is required (10 W).	1. Operator access to tape reels is required.
		4. K band antenna assembly (M130)	4-ft diam parabolic	1. External location. 2. Antenna axis must be aligned with the local Earth vertical. 3. Antenna mounting base must be capable of alignment within ±0.1° of attitude reference system in each orthogonal axis. 4. Antenna gimbal mount must enable ±50° azimuth and ±30° elevation antenna travel. 5. Antenna articulation envelope is a 6-ft diam sphere. 6. Two pressure feedthroughs required for antenna power and wavelength leads. 7. Proximity to other equipment not critical so long as viewing angles of antenna are unobstructed.	1. See Figure 6-8. 2. An airlock sized for two crewmen and equipment is required for antenna erection. 3. Antenna installation and alignment with attitude reference system requires use on manually operated optical equipment. This requires suitable windows and vision paths between ARS and the antenna. 4. Antenna erection equipment will be self contained in antenna package. 5. The antenna size noted is estimated minimum; a 10-ft diam antenna is desirable. 6. Erection is by connecting firm pieces, not inflation.
		5. S band antenna assembly (M140)	2-ft diam parabolic	1. Same as K band antenna above except articulation envelope must be 4-ft diam sphere.	1. Same as K band antenna notes. 2. Antenna size noted is estimated minimum; a 4-ft diam or larger antenna is desirable.
		6. Power supply (M150)	12x3x4	1. Internal location. 2. Cable lead length not critical 3. Cold plate cooling or equivalent is necessary (10 W).	1. See Figure 6-8.

Table 6-1 (page 4 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirements	Remarks
A-4	Infrared radiometry	1. Operator console and display (I100)	9x12x12	1. Internal location at a console. 2. Cable lead length not critical. 3. Cold plate or equivalent cooling is necessary (8 W).	1. See Figure 6-10 and 6-11.
		2. Controller (I-110)	6x3x3	1. Internal location. 2. Cable lead length not critical. 3. Cold plate or equivalent cooling is necessary (5 W).	1. See Figure 6-10.
		3. Data recorder (I-120)	12x6x12	1. Same as radar data recorder.	
		4. IR sensor unit (I-130) optics assembly	6x6x6 5x5x10	1. External location. 2. Mounting alignment and gimbal (sensor) pointing direction same as radar or microwave antennas, i.e., ±0.1° with respect to ARS, ±50° azimuth, ±30° elevation; nominal sensor axis along Earth local vertical. 3. One pressure feedthrough for cable leads is required. 4. Proximity to other equipment should be as remote as possible; thermal sources must be outside field of view of sensor.	1. See Figure 6-10 2. An airlock sized for two men and an IR sensor is required for external sensor installation. 3. Sensor installation and alignment with attitude reference system requires use of manually operated optical equipment. This requires suitable windows and vision paths between ARS and the sensor.
A-5	Cosmic dust measurement	1. Detector array, frame, and mast and sensor detectors. 2. Data display and mast control panel	48x24x48 6x6x6	1. External installation--in accordance with Figure 6-12. 2. Four arrays required spaced 90° apart on circumference of laboratory. 3. Shading or obstructions from other experiments or equipment must be avoided. 4. Pressure feedthrough for cables is necessary; may be a common feedthrough with other electrical wiring. 5. Cable lead length not critical. 6. Display readout and mast control is necessary from laboratory interior.	1. See Figure 6-12. 2. An airlock for periodic crew access to masts is necessary. 3. A console for mast control and data management is desirable.
A-6	High energy particulate radiation on organic materials	1. Radiation secure storm cellar and sample tube holder plus samples	16x8x6	1. Internal location--anywhere in pressurized area. 2. Daily access by crew for observation is necessary.	
		2. Internal sample tube holder plus samples	35x30x1	1. Internal location--anywhere in pressurized area; proximity to storm celler set is desirable. 2. Same as 2 above.	
		3. External sample tube holder	35x30x1	1. External location--close to a vision port for daily crew observation. 2. No connections are necessary. 3. Access by crew is necessary for occasional sample exchange or observation. 4. Sample holder must be placed in a location unobstructed from solar and space radiation.	

Table 6-1 (page 5 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirements	Remarks
A-7	Measurement of solar absorptivity and thermal emissivity of various materials by spectrometry	1. Rack holder and specimens	36x36x9	1. External location having unobstructed view of both the sun and the deep space for 15 min.each for every orbit. 2. The assembly must be gimballed to enable constant viewing angle to the sun for the sun viewing portion of each orbit; the assembly must look at neither sun or earth during deep space portion of each orbit. 3. The assembly must be thermally isolated and protected from the vehicle (calibrated heating and cooling to the specimens is required). 4. Feedthroughs for electrical wiring (samples + rack gimbal control) and coolant lines is required. 5. Cable length not critical.	1. A personnel airlock is necessary for periodic access to the external rack holder. 2. Calorimetric measurements of equilibrium temperature conditions of the samples is necessary (heating during sun portion cooling during deep space portion). The observation is not continuous.
		2. Integrating sphere reflectometer and light source	12 ft x 12 ft x 12 ft	1. Internal location convenient for operator control. 2. Proximity to rack is not necessary; rack samples are periodically brought inside for analysis. 3. Electrical power to equipment is necessary.	
		3. Data recorder and controller	6x6x6	1. Internal location convenient for operator control. 2. Cable lead length not critical. 3. Interface with laboratory measurement apparatus is necessary for calorimetric determinations and for stripchart recording.	
A-8	Spacecraft thermal equilibrium	1. Thermocouples and wiring	0.1 cu ft	1. Thermocouples installed at selected positions throughout laboratory. 2. Cable length to data recorder equipment not critical.	
		2. Data recorder (tape)	12x6x12	1. Same installation requirements as data recorders above.	1. It is possible that this data recorder may be shared with other experiments such as cosmic dust experiment above. 2. Operator verbal input to recorder is necessary.
A-9	Evaluation of communications techniques	1. Low noise amplifier	12x6x2	1. Internal installation. 2. Cable lead length not critical. 3. Cold plate or equivalent cooling is required (8 W). 4. Wiring feedthrough port to antenna is necessary; feedthrough may be combined with other experiment feedthroughs.	
		2. Sounding receiver	12x12x30	1. Same requirements for installation as low noise amplifier above (A-9 item 1). 2. Cold plate cooling or equivalent is required (100 W).	1. Operator access to equipment for control operation is necessary.

Table 6-1 (page 6 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirements	Remarks
		3. Sweep scale converter	12x6x2	1. Same requirements for installations as A-9 Equipment Item 1 above. 2. Cold plate cooling or equivalent is required (8 W).	1. Operator access to equipment for control operation is necessary.
		4. Spectograph	12x12x18	1. Same requirements for installation as A-9 Equipment Item 1 above. 2. Cold plate cooling or equivalent is required (45 W).	1. Operator access to equipment for control operation is necessary.
		5. Data recorder	12x6x12	1. Same installation requirements as other data recorders.	1. Operator access to equipment for control operation is necessary. 2. Data recorder may be shared with other experiments during non use times.
		6. Antenna	Crossed dipole antenna 150 ft	1. External installation on end of solar cell mast. 2. Despite large antenna size, obstructions in radiation pattern must be minimized. 3. Antenna must be unfurled (or erected) after orbit attainment. 4. RF feed cable must bridge the solar cell mast to laboratory joint.	1. See Figure 6-13. 2. Airlock required for access to antenna for adjustment and erection.
A-10	Fatigue test of Materials after exposure to space environment	1. Test machine	24x12x12	1. Installs in experiment airlock; pressure seal is required. 2. Storage facilities for test machine during non use time is necessary. 3. Power and instrument wiring to equipment while operating in the airlock is necessary; cable lead length not critical.	1. See Figure 6-14. 2. A console adjacent to airlock for recorder equipment and test operation is necessary. 3. Airlock use for crewman plus samples is required for access to sample holder.
		2. Timer	0.01 cu ft	1. Assume part of standard laboratory equipment.	
		3. Temperature recorder	12x3x5	1. Internal installation convenient to test machine. 2. Lead length not critical. 3. Recorder may be shared during non use times.	
		4. Metal test samples and sample holder	36x24x1	1. External location convenient for crew to change samples periodically. 2. Position of holder must allow unobstructed exposure to the space environment.	
A-11	Ionization radiation measurements and properties	1. Crew dosimeters		1. Worn on person-- no installation requirements.	
		2. Photo processor (film badge)	12x6x5	1. Same installation requirements as 9-in. by 9-in. processor in photography experiment except for size.	
		3. Electrometer recharge	12x3x5	1. Location of internal installation not critical. 2. Cable length not critical. 3. Cold plate cooling or equivalent (5 W).	

Table 6-1 (page 7 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirements	Remarks
		4. Film storage--radiation secure	12x6x5	1. Internal installation--location not critical. 2. Refrigeration during storage is necessary.	1. Possible to combine with sto for photo experiment.
		5. Geiger counter (2 required)	12x6x5 each	1. Portable, battery operated equipment; no installation requirement. 2. Storage for counters is necessary.	
		6. Radiation sensor package (4 required) (Scintillation and proportional counters, sandwich spectrometer, and power supply)	12x10x10 each	1. Internal location--on vehicle circumference at 0°, 90°, 180°, 270°. 2. Power and instrumentation leads to data management system is required; lead length not critical.	
		7. Space radiation telescope (SRT)	6x3x3	1. External operation--installed on articulating boom via experiment airlock. 2. SRT must have spherical coverage despite laboratory attitude. 3. Boom must have signal and power leads such that SRT may be operated remotely from laboratory console. 4. Storage for SRT when not in use convenient to airlock is desirable.	1. See Figure 6-15.
		8. SRT electronic package	12x12x12	1. Internal location 2. Cold plate or equivalent cooking is necessary (15W).	1. See Figure 6-15.
		9. Display and data readout panel	12x6x6	1. Internal location adjacent to boom controller. 2. Same requirements as other data and control panels.	
A-12	Evaluation of behavioral responses in the orbital environment Part I (standard behavioral measurements)	1. Behavioral measurement test console	Console + Equipment (see Figure 6-16)	1. Console and equipment as noted in Figure 6-16. 2. Space for two operators and equipment storage is necessary. 3. Installation requirements will be the same as the standard MORL console and work space.	
		2. Behavioral measurement chair	(See Figure 6-16)	1. Installation requirements typical for cockpit articulating seats. 2. Power leads and control wiring are necessary. 3. Space for chair articulation as noted in detailed experiment.	

Table 6-1 (page 8 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirement	Remarks
A-13	Evaluation of behavioral responses in the orbital environment, Part II (journal recording)	1. Tape recorder	12x6x4	1. Internal installation at behavioral console. 2. Same requirements as other tape recorder installations in operations deck of MORL.	1. See Figure 6-16.
A-14	Retention of skills learned in the orbital environment	1. Dexterity and tracking apparatus	12x6x6	1. Equipment contained in behavioral console.	1. See Figure 6-16.
A-15	Crew performance in orbital and reentry operations	1. Re-entry simulator 2. Rendezvous and docking simulator 3. Tracking simulator	12x8x6 12x8x6 12x8x6	1. Simulators installed at behavioral console.	1. See Figure 6-16.
A-16	Ventilation of respired gases in manned space enclosures	1. Gas Chromatograph	12x12x12	1. Internal location at a work console in which suitable lighting, counterspace, controls, and operator space are provided. 2. Three modules are included--helium reservoir, analyzer, as well as a readout and control module. 3. Plumbing lines, vent to space, wiring, and control circuitry are necessary.	
		2. Calibration gas mixtures and radiation cells for gases	12x3x5	1. Assume incorporated in common radiation secure storage area (a standard laboratory supplied item).	
A-17	Evaluation of life support systems to detect microbiological and chemical contaminants	1. Incubator (37°C ± 0.5°C)	12x12x12	1. Internal location where liquids and biological growth equipment may be handled and separately ventilated.	
		2. Sterilizer (steam)	8x8x10	1. Internal location where liquids and biological growth equipment may be handled and separately ventilated.	
		3. Microbiological collection and growth equipment	0.2 cu ft (many small pieces)	1. Internal installations consisting of small diameter, filtered bypass lines in the air and water supplies, and smear taking equipment for use in the galley, hygiene, etc. 2. A location suitable for transferring and handling the microbiological samples from filters to growth plates and for preparing growth plate equipment.	

Table 6-1 (page 9 of 9)

Ref Para No.	Experiment	Equipment Item	Operating Size (in.) (lxhxw)	Installation/Configuration Requirements	Remarks
		4. Sterile water supply	6x6x6	1. Internal location suitable for handling free liquids in small quantities.	
		5. Microscope and attachments	18x12x10	1. Internal location suitable for microbiological identification. 2. Equipment consists primarily of microscope and attachments, chemical staining apparatus, slides and slide library.	
A-18	Force producing capabilities of operators in zero gravity	1. Mechanical manipulative equipment	3.6 cu ft	1. Internal--equipment consists of mechanical manipulative equipment with calibration settings to enable measurement of force input by human operators in various modes of operations. Restraint systems are also part of the equipment. 2. The installation must be near biomedical recording equipment and must be mounted on surfaces which have sufficient rigidity to enable maximum force input without failure of mounting surfaces. 3. Sufficient work space must be available for two operators. The space should be sufficient to accommodate one of the crewmen in a pressure suit. 4. EC/LS support lines and outlets for pressure suit operation must be provided. 5. Storage facilities for the manipulative equipment must be provided when equipment is not in use. The volume is 3.6 cu ft.	

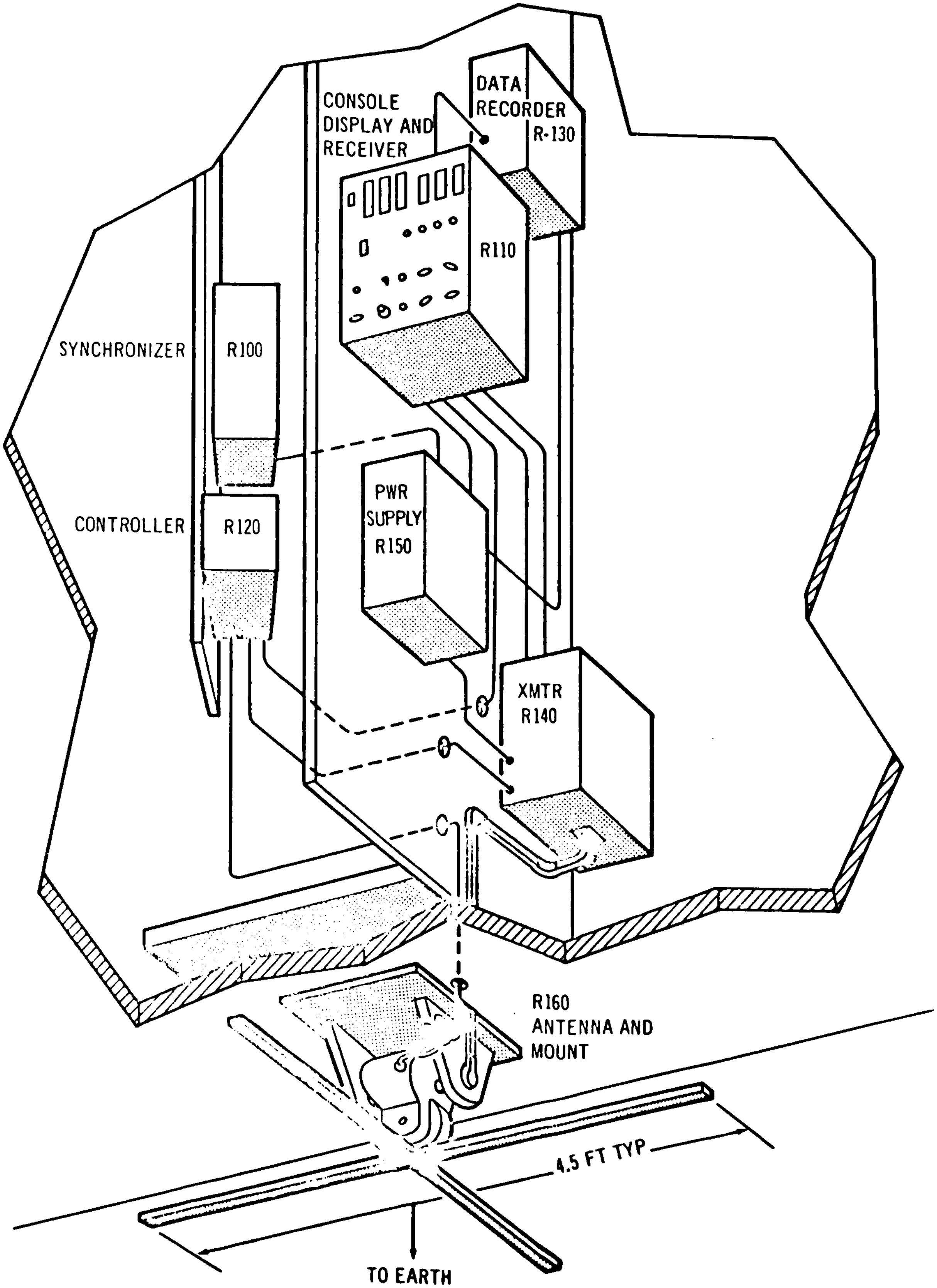


Figure 6-2. Radar System

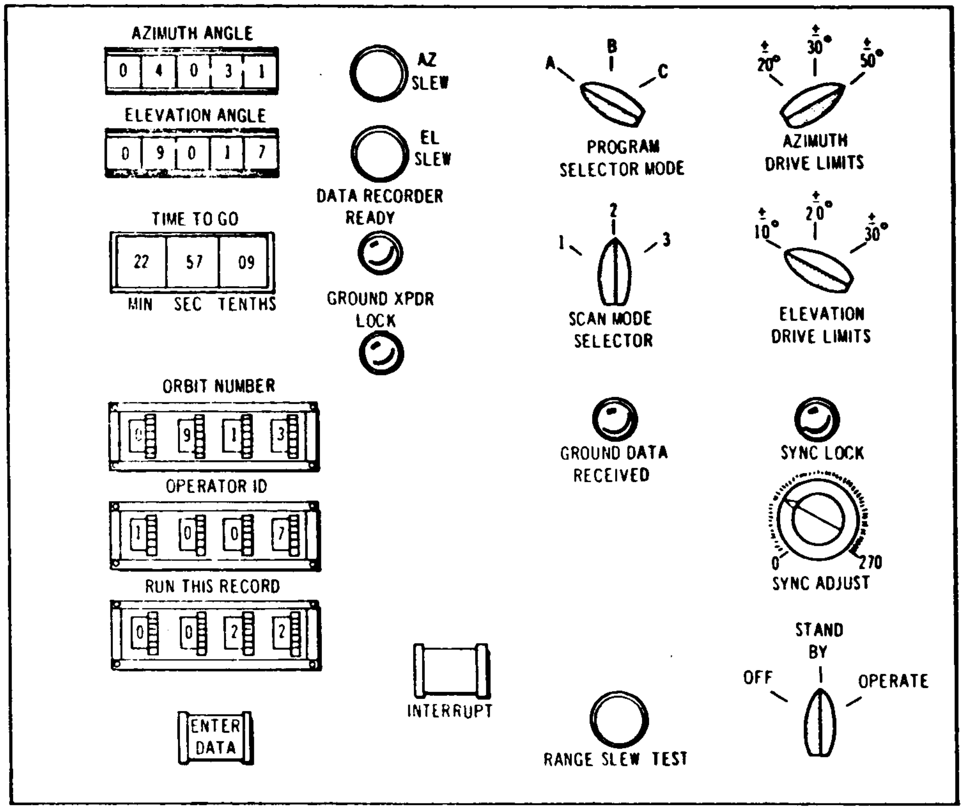


Figure 6-3. Radar Display

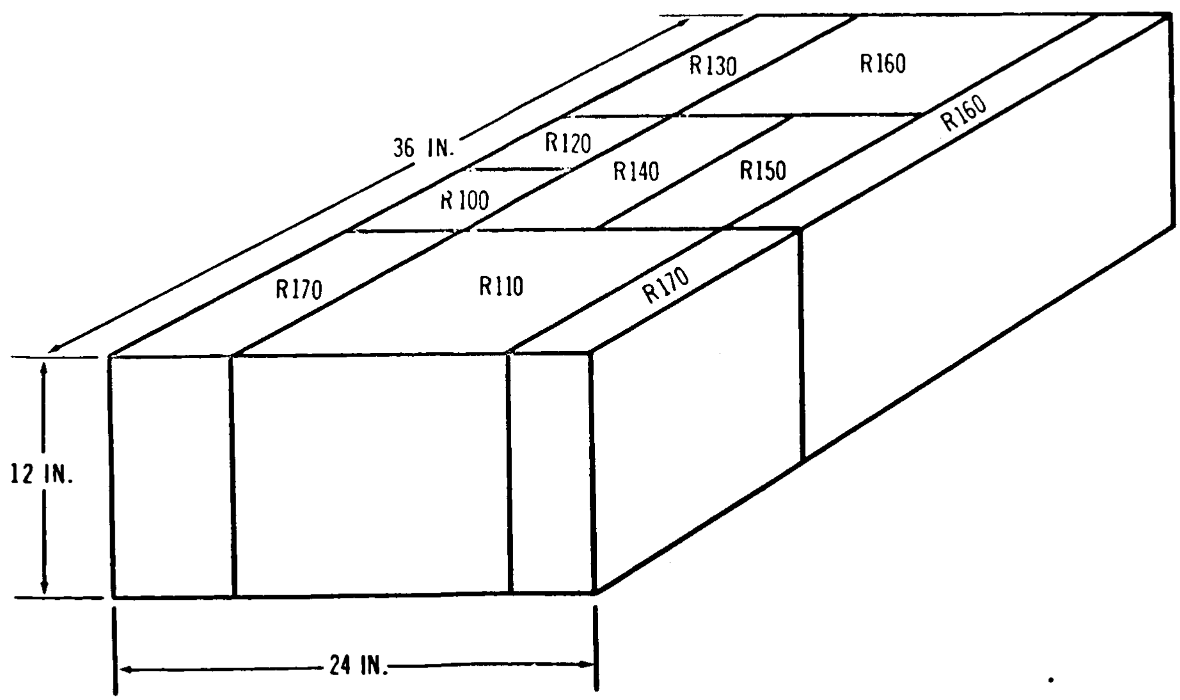


Figure 6-4. Packaged Configuration, Radar R-101, Experiment 252

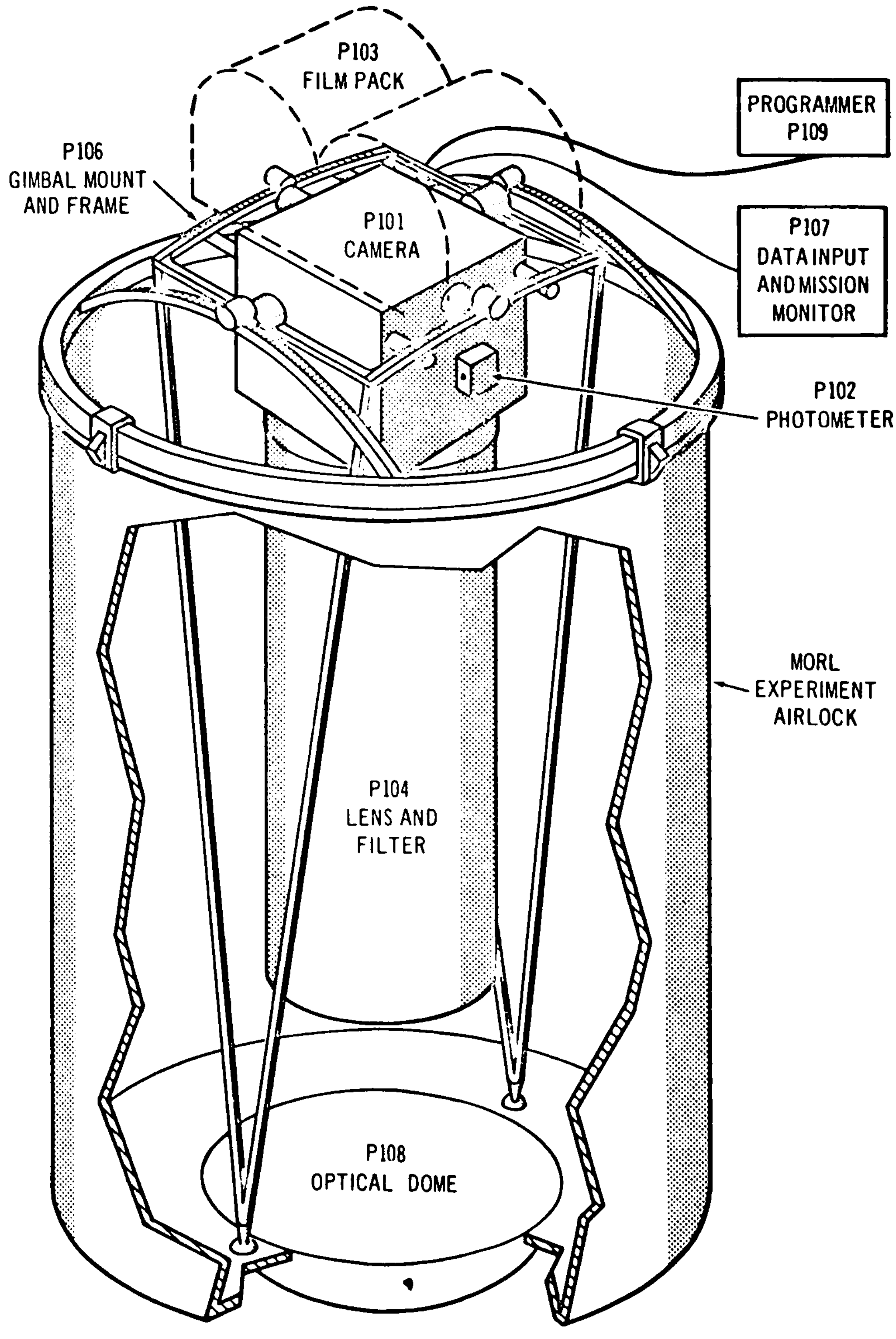


Figure 6-5. Photography System

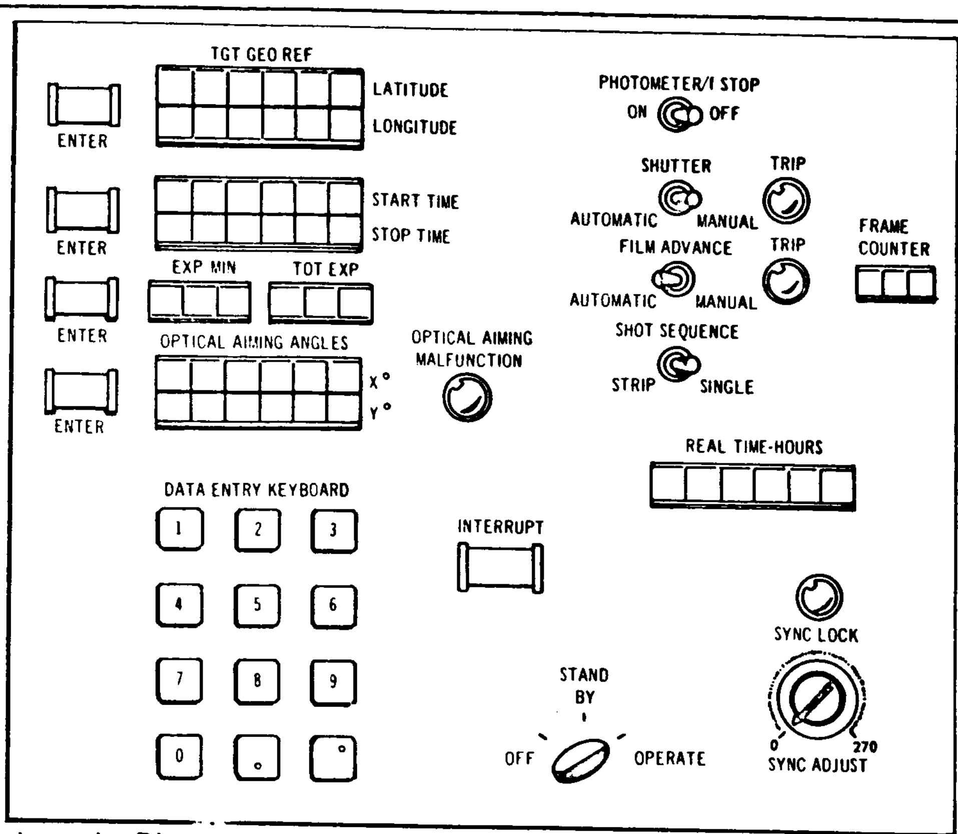


Figure 6-6. Photography Display Panel

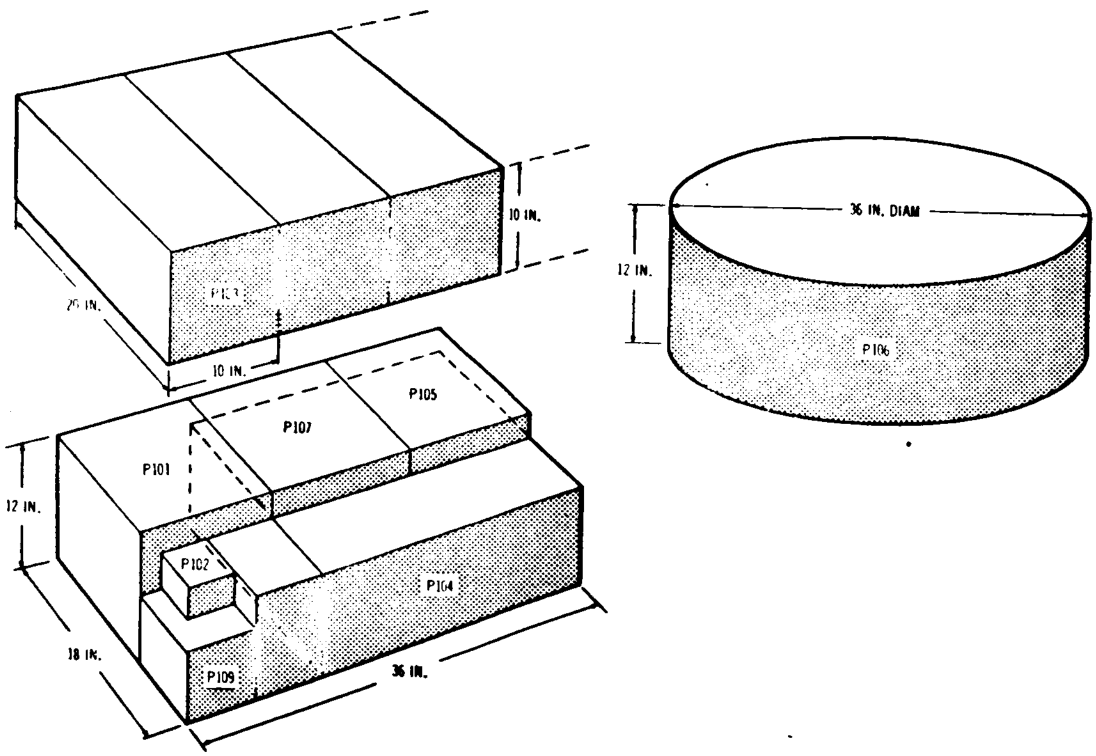


Figure 6-7. Packaged Configuration -- Photography

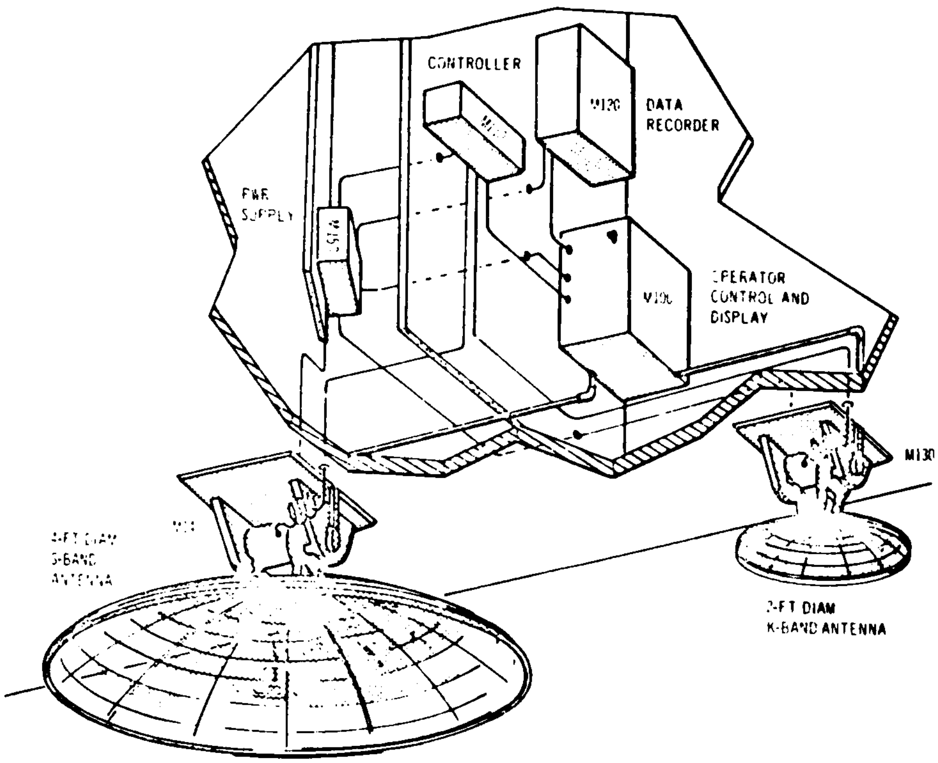


Figure 6-8. Microwave System

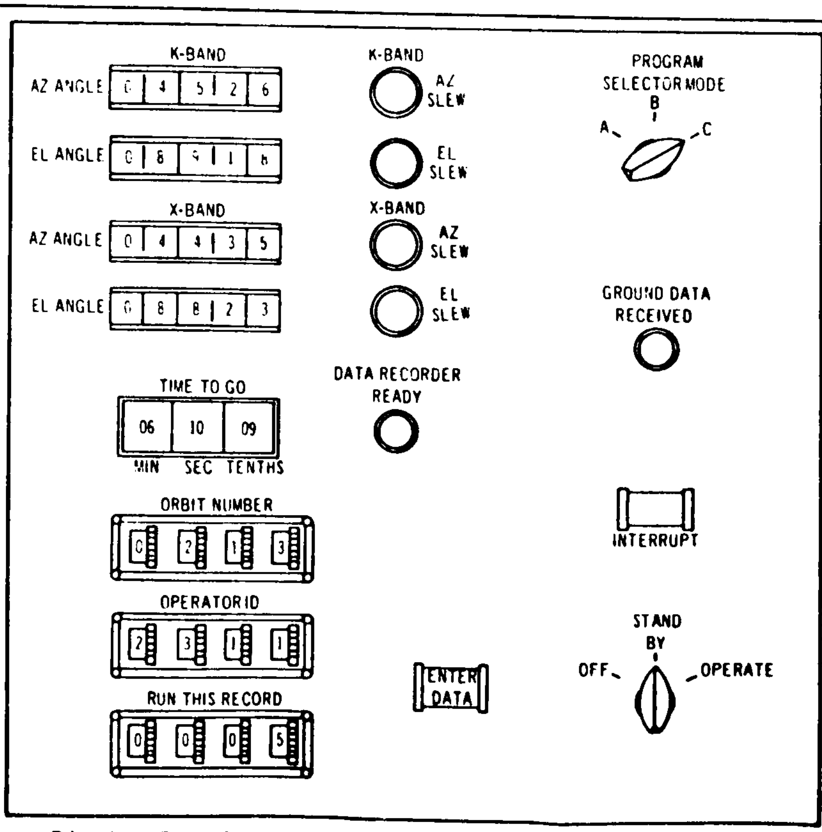


Figure 6-9. Microwave Display Panel

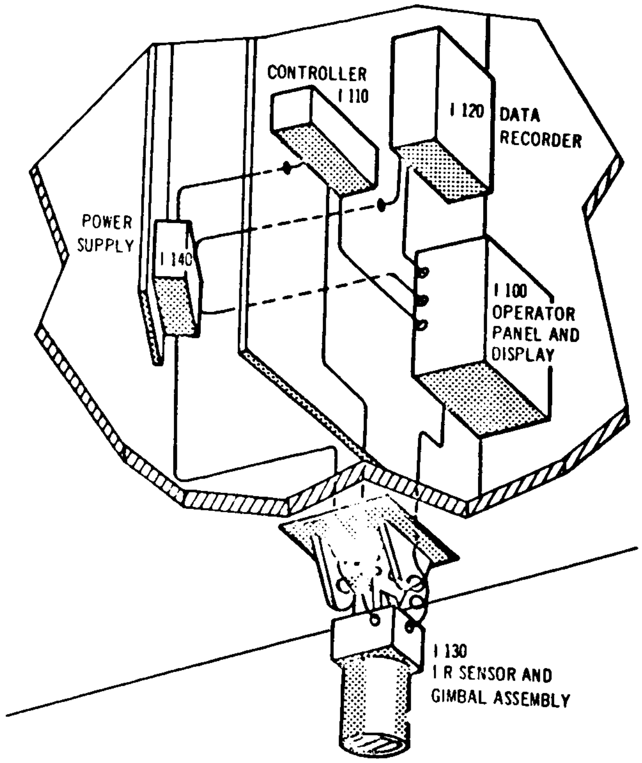


Figure 6-10. IR System

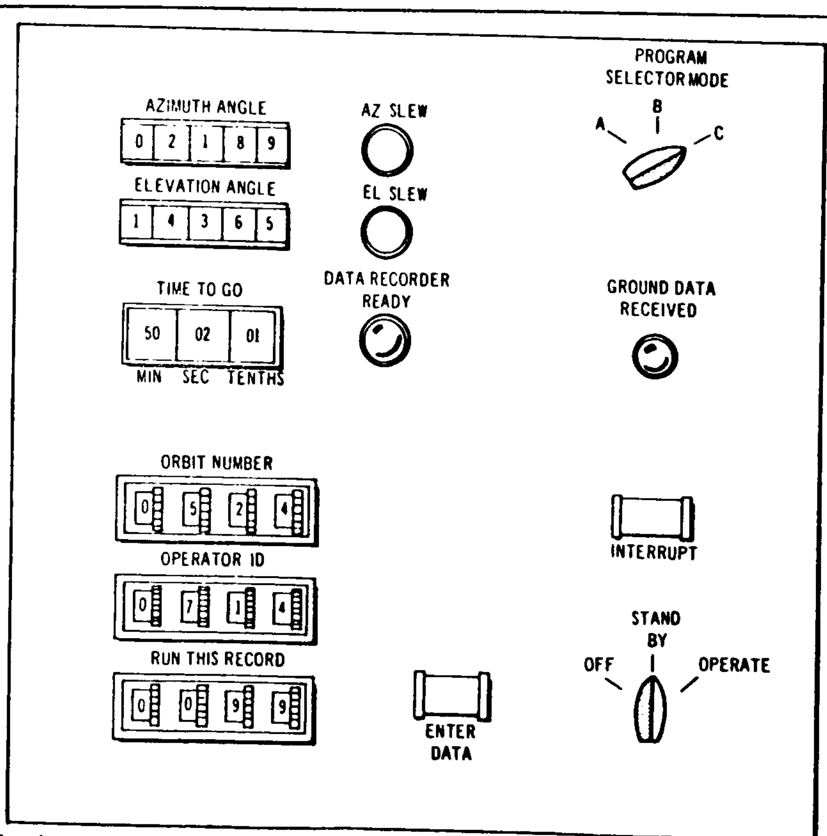


Figure 6-11. IR Display Panel

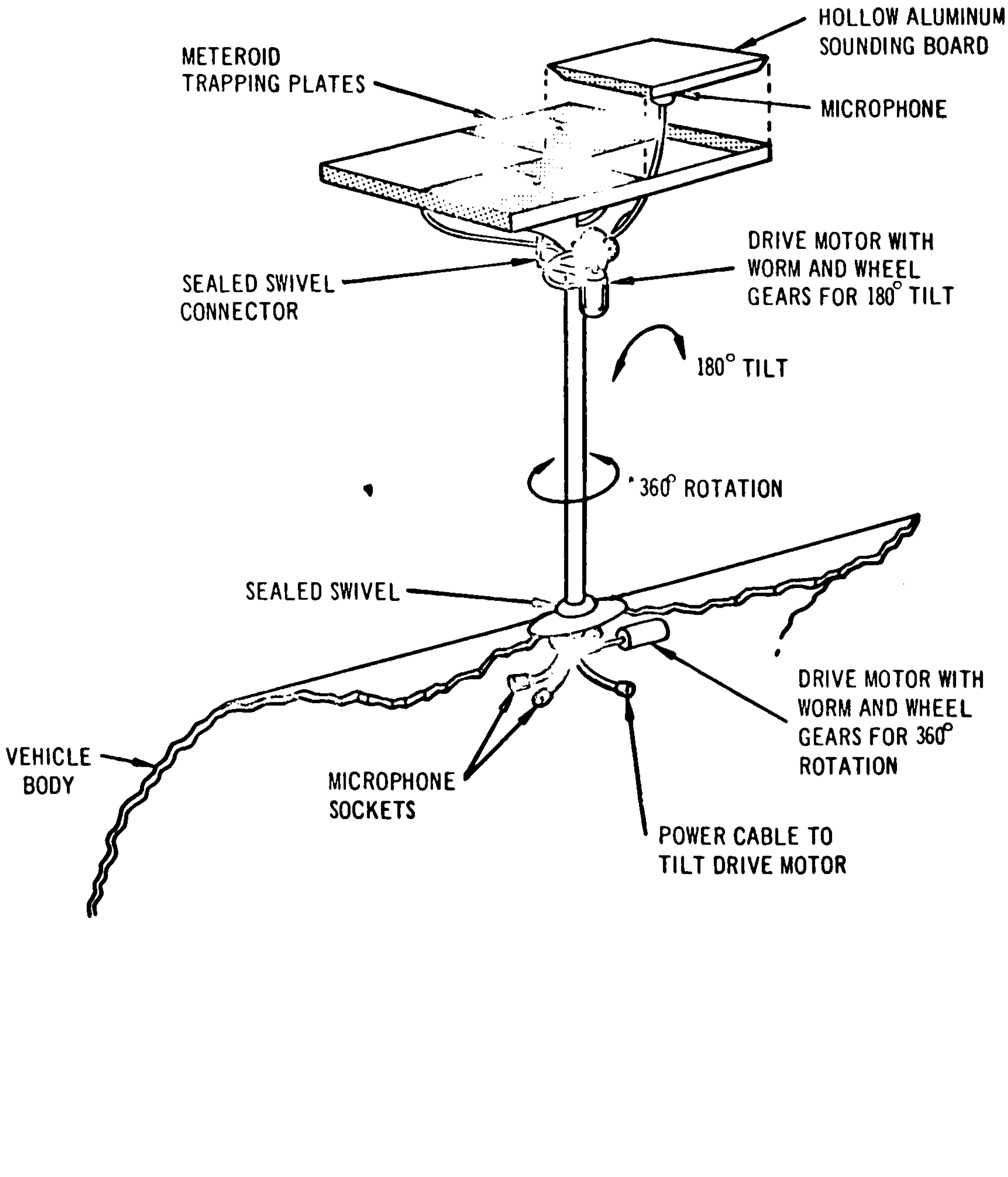


Figure 6-12. Cosmic Dust and Meteroid Capture Panel Assembly

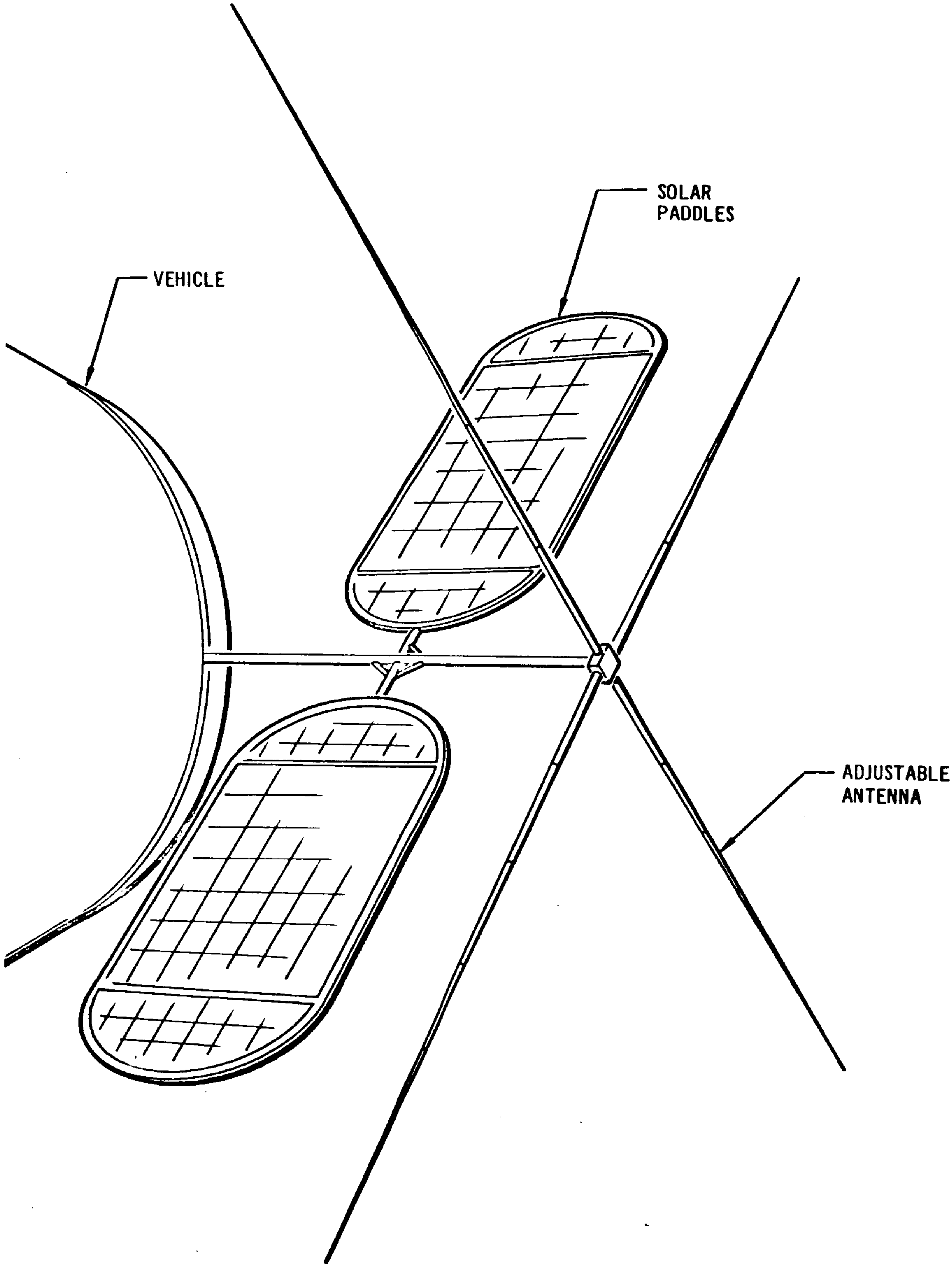
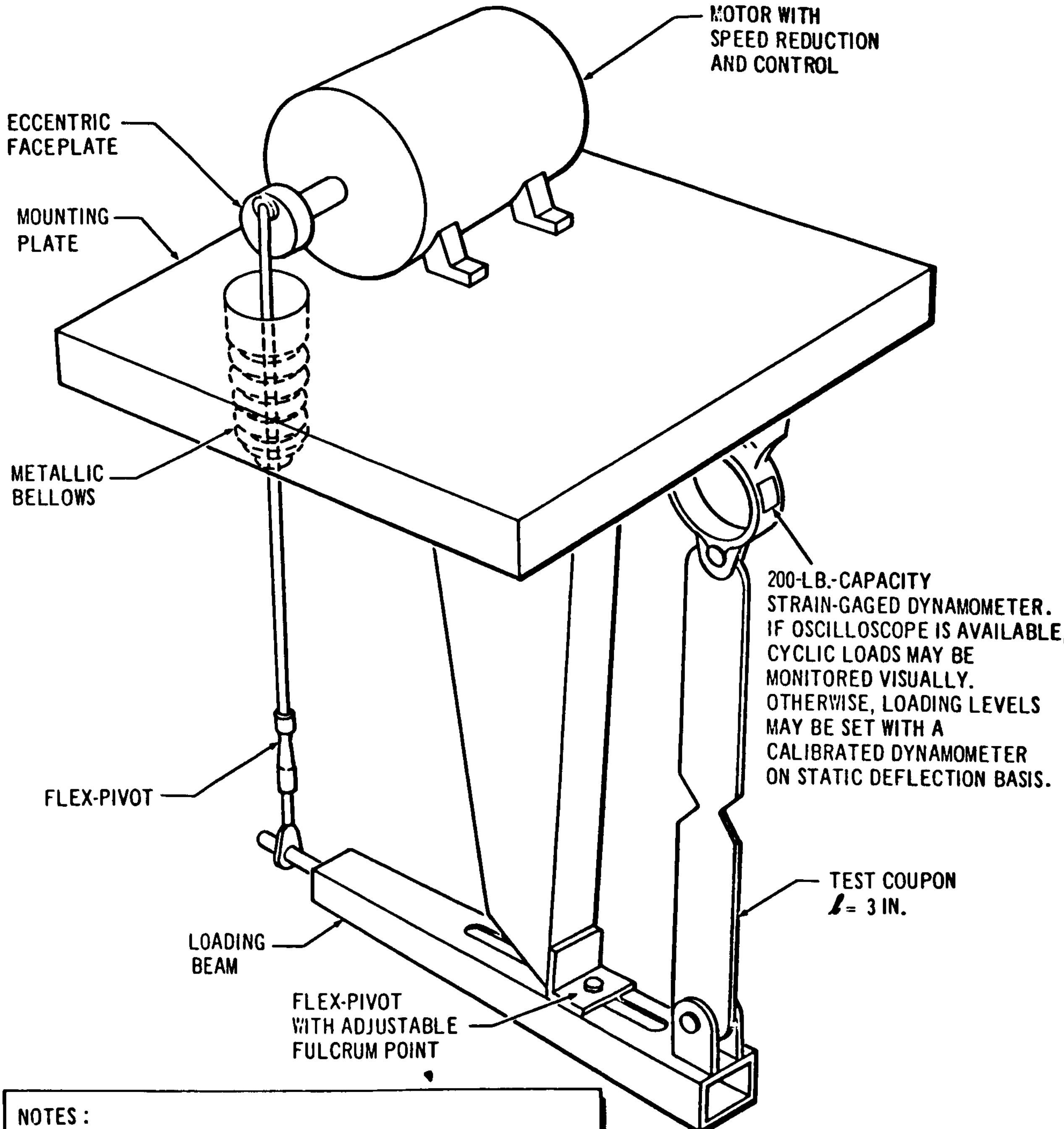


Figure 6-13. Suggested Mounting for Communications Experiment Antenna



NOTES:

1. OVERALL HEIGHT : APPROXIMATELY 8 IN.
2. MOUNTING PLATE SEALS IN EQUIPMENT AIRLOCK SO THAT SPECIMEN SIDE OF PLATE IS EXPOSED TO SPACE ENVIRONMENT WHILE MOTOR OPERATES IN PRESSURIZED ATMOSPHERE

Figure 6-14. Fatigue Tests of Materials

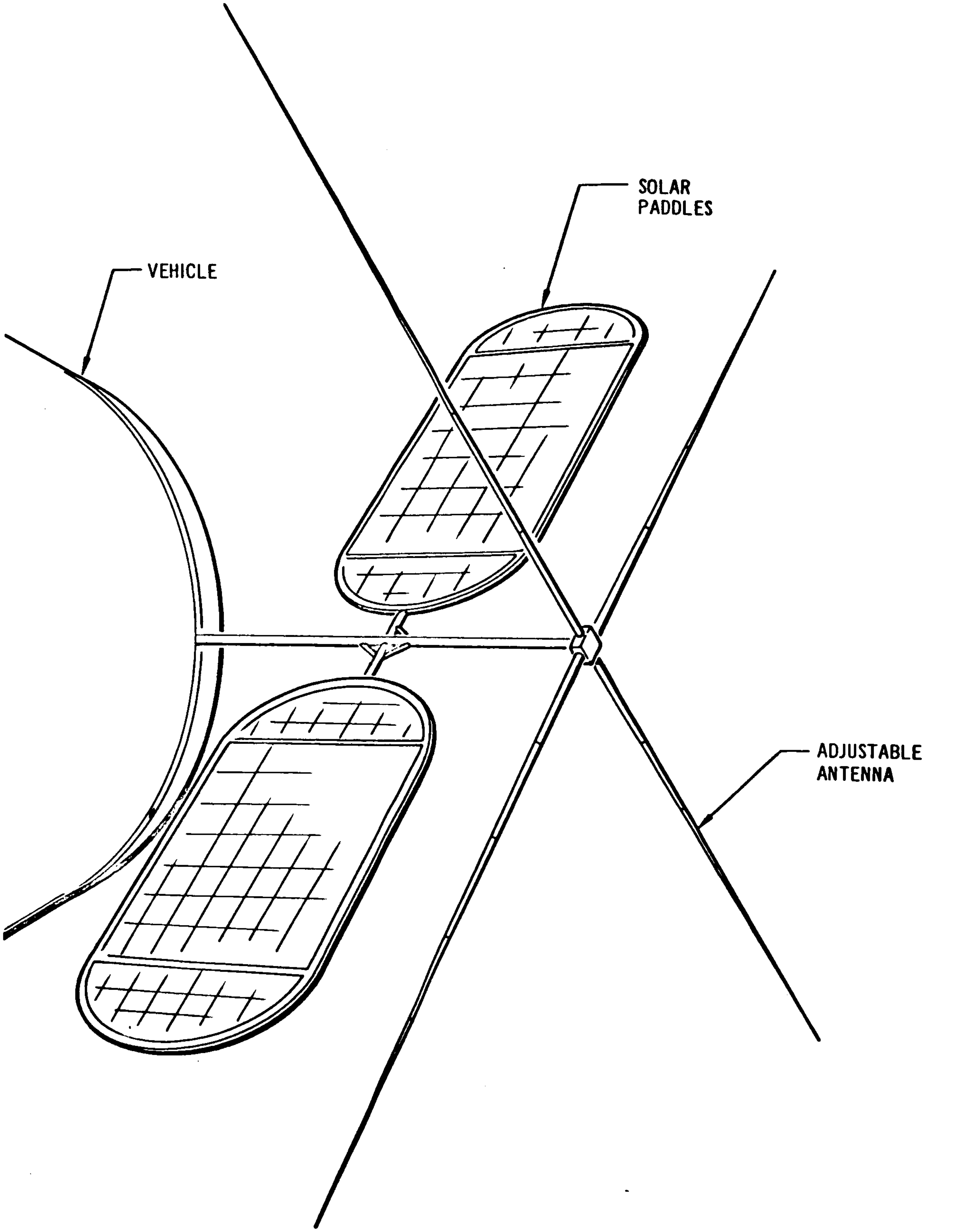
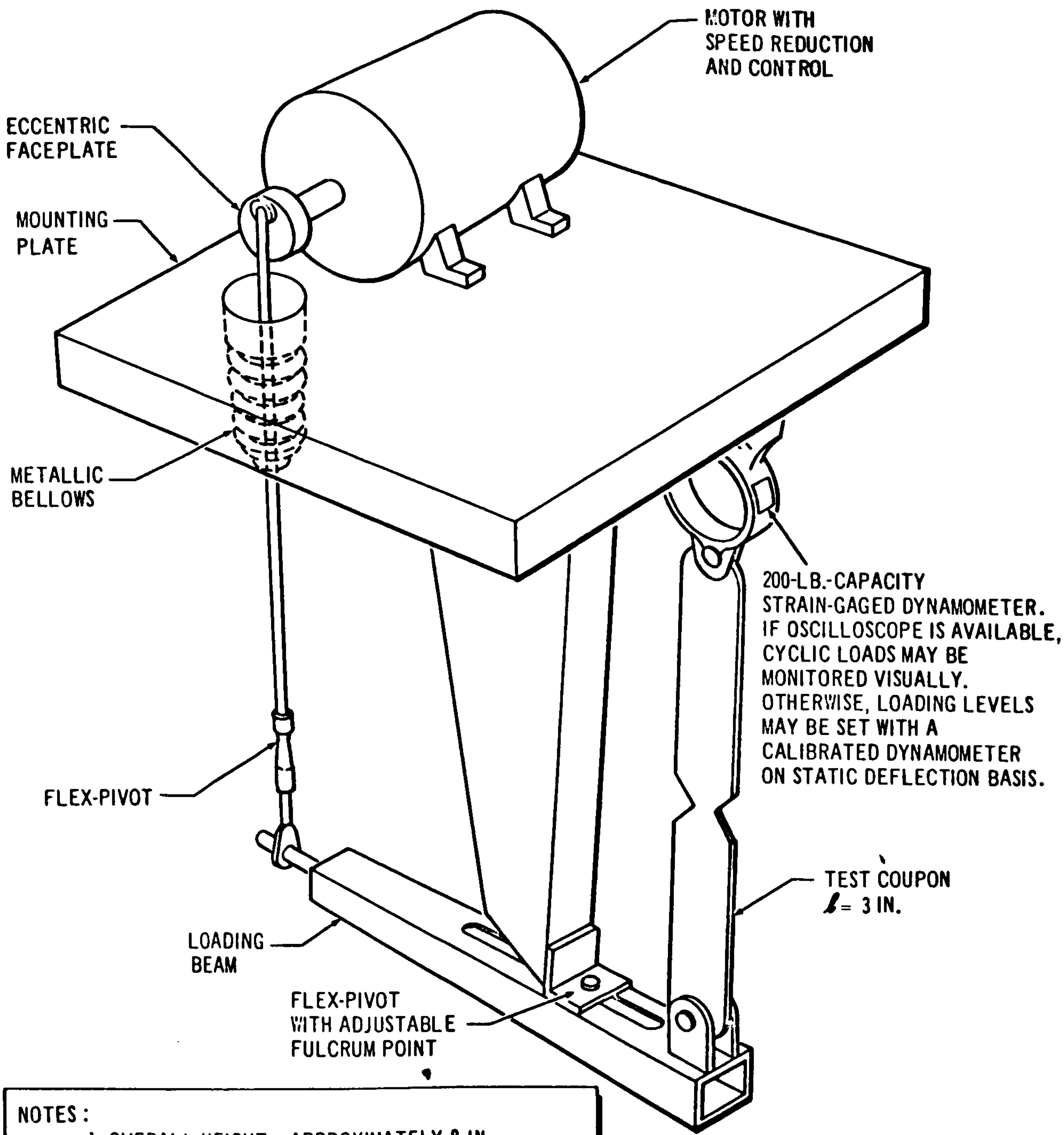


Figure 6-13. Suggested Mounting for Communications Experiment Antenna



NOTES:

1. OVERALL HEIGHT : APPROXIMATELY 8 IN.
2. MOUNTING PLATE SEALS IN EQUIPMENT AIRLOCK SO THAT SPECIMEN SIDE OF PLATE IS EXPOSED TO SPACE ENVIRONMENT WHILE MOTOR OPERATES IN PRESSURIZED ATMOSPHERE

Figure 6-14. Fatigue Tests of Materials

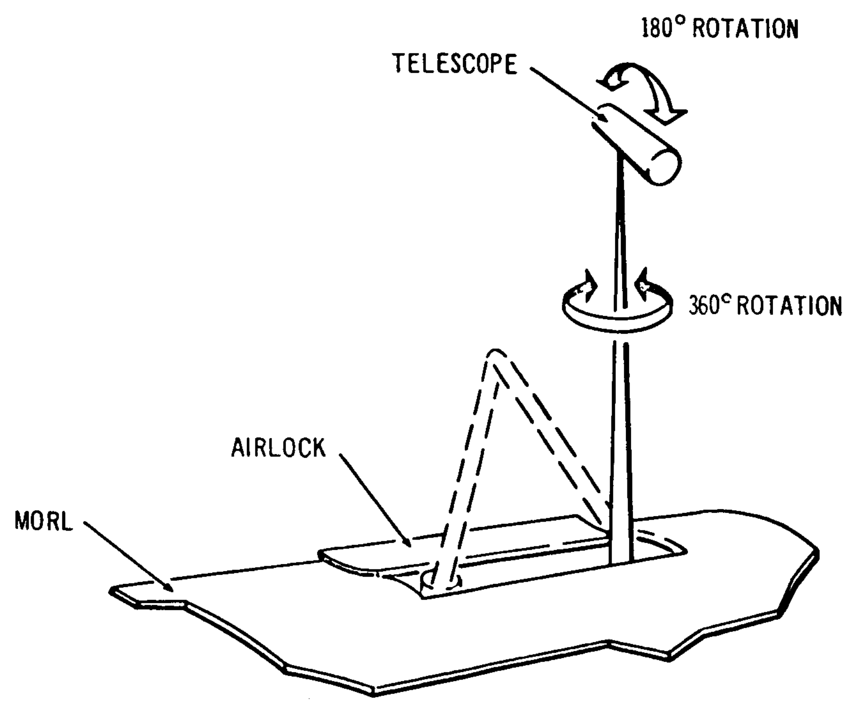


Figure 6-15. Space Radiation Telescope

Figure 6-16. Biomedical Behavioral Console

Table 6-2

EXPERIMENT EQUIPMENT INSTALLATION LOCATION AND VOLUME REQUIREMENTS (page 1 of 2)

Para No.	Experiment Title	Equip. Item (from Table 6-1)	Biomedical Console Vol	Biomedical Console Panel Area	Scientific Console Vol	Scientific Console Panel Area	Hangar Console Vol	Hangar Console Panel Area	Analytical Console Vol	Analytical Console Panel Area	Biological Test Room Vol	Biological Test Room Panel Area	Storm Cellar Vol	Equipment Storage Vol	Aligned Beam lxwxh	Articulating Boom lxwxh	Experiment Airlock lxwxh	Press Feedthru (No. Req)	Miscellaneous Location
A-1	Radar	1			0.25	-								36 in. x 12 in. x 21 in.					
		2			1.0	10x12													
		3			0.25	-													
		4			0.5	12x6													
		5			0.66	-													
		6			0.5	-													
		7													3 ft diam sphere			2	
A-2	Photography	1 to 6											1.0 cu ft	36 in. diam x12 in. 36 in. x12 in. x 18 in.			36 in. diam x24 in.		
		7														9 in.	[illegible] in. R Hemis.		
		8					0.28	10x12											
		9					0.13	6 x 6											
		10									5.0	--							
		11							1.5	3 x 4									
		12							1.0	6 x 6									
A-3	Microwave radiometer	1			0.75	12x9								0.75 cu ft					
		2			0.06	-								0.06 cu ft					
		3			0.5	12x6								0.05 cu ft					
		4												1.0 cu ft	6 ft diam sphere			2	
		5												1.0 cu ft	4 ft diam sphere			2	
		6			0.84	-								0.84 cu ft					
A-4	IR radiometer	1			0.75**	9x12								0.75 cu ft					
		2			0.03**	6x3								0.03 cu ft					
		3			0.5**	12x6								0.5 cu ft					
		4												0.27 cu ft	0.27 cu ft			1	
A-5	Cosmic dust measurement	1												--				1	4 masts on aft interstage
		2			0.13	6x6								--					
A-6.	Radiation on material	1											0.45	--					Any interior location 15x10x1 in. Exterior location (assume aft)
		2												--					Any interior location 15x10x1 in. Exterior location (assume aft)
		3												--					Any interior location 15x10x1 in. Exterior location (assume aft)
A-7	Solar	1												--				2ΔΔ	Exterior--part sun, part shade 36 x 36 x 9 in.
		2							1.0	12x12				--					
		3			0.12	6x6								--					
A-8	Vehicle thermal equilibrium	1												--					Multiple locations inside
		2			0.5Δ	12x6								--					
A-9	Communication techniques	1			0.84	--								--					
		2			2.5	--								--					
		3			0.84	12x6								--					
		4			1.5	12x12								--					
		5			0.6Δ	12x6								--					
		6												--				1ΔΔ	Antenna located on solar cell mast
A-10	Material fatigue tests	1												24x12x12			24x12x12		
		2					0.1	5x3						--					

* Volume in cu ft
** Dimensions in in.

\#\# Alternate location at hangar console

Δ Common data recorder to experiment A-1, A-3 or A-4
ΔΔ Common feedthrough housing possible

Table 6-2 (page 2 of 2)

Para No.	Experiment Title	Equip. Item (from Table 6-11)	Biomedical Console Vol	Biomedical Console Panel Area	Scientific Console Vol	Scientific Console Panel Area	Hangar Console Vol	Hangar Console Panel Area	Analytical Console Vol	Analytical Console Panel Area	Biological Test Room Vol	Biological Test Room Panel Area	Storm Cellar Vol	Equipment Storage Vol	Aligned Beam lxwxh	Articulating Boom lxwxh	Experiment Airlock lxwxh	Press Feedthru (No. Req)	Miscellaneous Location
		3					0.1	12x3						--					
		4																	External location (assume aft end)
A-11	Ionization radiation	2												--					
		3			0.1	12x3								-					
		4												--					
		5												12x6x10					
		6												-					Internal at the 0°, 90°, 180°, 270° positions of lab
		7												6x5x5		6x5x5	6x5x5	1*	
		8			1.0	--								--					
		9			0.25	12x6								--					
A-12	Behavioral responses I	1	See Figure 6-16											--					
		2	See Figure 6-16											--					
A-13	Behavioral responses II	1	0.17	12x6										--					
A-14	Retention of skills	1	0.25	6x6										--					
A-15	Crew performance	1	0.33	12x8										--					
		2	0.33	12x8										--					
		3	0.33	12x8										--					
A-16	Ventilation of respired gases	1							1.0	12x12				--				1	
		2											12x3x5						
A-17	Evaluation of EC/LS	1									1.0	12x12		--					
		2									0.07	8x8		--					
		3																	EC/LS equipment instl
		4									0.12	6x6		--					
		5									1.25	--		18x12x10					
A-18	Force capabilities	1												5.6 cu ft					At Biomedical station adjacent to console
	TOTAL		See Figure 6-16		14.87	7.7 sq ft	0.52	1.4 sq ft	4.5	2.3 sq ft	5.64	2.2 sq ft	2.36 cu ft	24.[illegible] cu ft					

* Volume in cu ft
** Dimensions in in.

* May be combined into same housing

be provided from the more remote position at the scientific console in the operations deck. The console should be suitable for the installation of the same standard laboratory measurement apparatus which is mounted on the scientific console. This interchangeability ensures efficient use of the equipment. An example would be the installation of voltmeters, counters, oscilloscopes, and so forth, at either location. In addition, the console should be designed for rapid and simple exchange of unique pieces of experimental equipment such as control and data panels associated with certain experiments. The console must be sufficiently large for one operator; however, a console size permitting operation by two operators is desirable. A larger panel would permit greater flexibility and simultaneous operation of two or more experiments. The 48-hour study indicates a console of fairly small dimensions, but subsequent analysis of the experiments may indicate requirements for a larger size. The console could relieve some of the work load on the scientific console located in the operations area. Sizing should be similar to the consoles in the operations deck; the MORL dimensional set up for consoles will be satisfactory.

6.2.1.2 Scientific Console

The MORL scientific console consists actually of two parts: one part contains the maintenance and laboratory trouble shooting apparatus, and the other is used for the setup and operation of experiments. The latter part is a one-operator console. The 48-hour study alone indicates that the panel should use at least 7.7 sq ft out of the total 10 sq ft of area available. Furthermore, the work load on a single test conductor for multiple sensor experimentation, such as IR and microwave radiometry and the radar experiments, is quite high, since three experiments must be controlled simultaneously during the short-duration target available time of approximately 10 min. Therefore, the addition of more scientific console space is recommended not only to gain additional panel space but also to allow two or more operators to work simultaneously during peak experimental loads. The hangar deck console may be used to satisfy some of this requirement, but it appears that it will still be necessary to have additional console volume at the scientific work station.

track, for pitch and yaw information, and one star to the side of the vehicle and approximately 90° from the first star, for roll information. A star tracker looking aft could be used as an alternate.

6. The ARS inertial reference system and the star tracker/horizon sensor package should be mounted in close proximity to each other on an integral attitude reference base (ARB).
7. The ARB and sensors must contain means for coordinated optical alignment with the experiment sensors noted above.
8. The ARS should be designed to ensure that it may be maintained and operated with minimum tools, equipment, and labor.

6.2.2 Alternate Configuration

The laboratory interiors requirements generated by the experiments examined in the 48-hour study are adequately satisfied by the baseline MORL interiors. The only exceptions are the addition of the hangar/test area console and, the enlarged scientific test station as discussed in Section 6.2.1. These changes appear to be easily accommodated in the baseline interiors design, and, therefore, no alternate interiors configurations were required during this study.

The requirements associated with providing means for attaching the oceanographic experiment sensors to the bottom side of the laboratory necessitated an investigation of the laboratory's exterior configuration. The oceanographic requirements coupled with the requirement to provide adjacent mounting provisions for the attitude reference sensors, made it necessary to examine several concepts. The concepts examined are illustrated in Figures 6-17 through 6-20. The major advantages and disadvantages of each approach are listed in the sections below.

6.2.2.1 Configuration I--Sensors Along MORL Side

This concept is illustrated in Figure 6-17. The figure shows the sensor mounting platform along the MORL side adjacent to the operations deck. The major advantages of this concept are as follows:

1. A rigid attachment to the MORL pressure vessel and floors thereby increases stability.

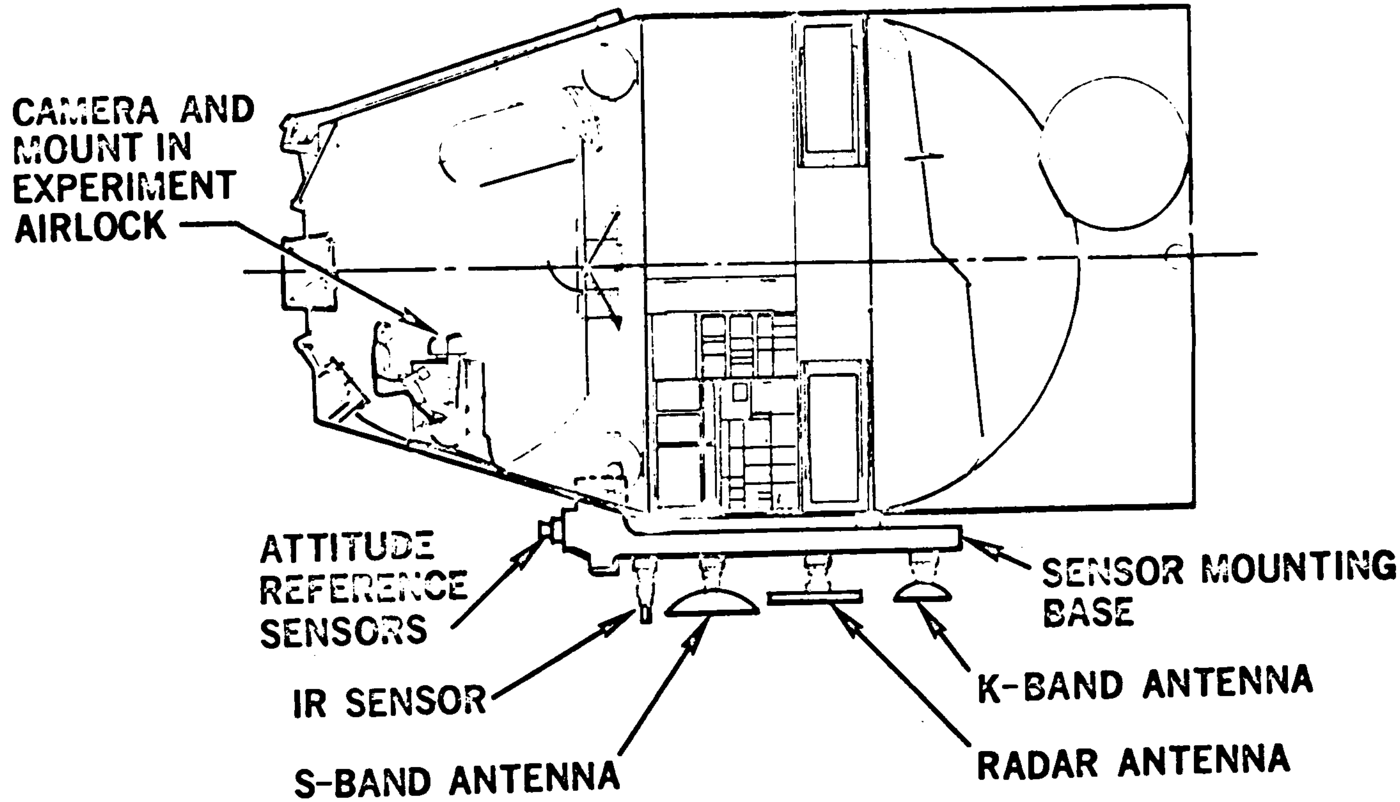


Figure 6-17. Configuration I - - Sensors on Side

2. Short-length rf waveguides and cable lengths to the experiment console.
3. Excellent visual reference to the operations deck.
4. Intermediate position between the solar cell panels and the stowed spacecraft which eliminates interference.
5. Good accessibility to the attitude mounting base.
6. Growth space for larger sensor equipment.

The major disadvantages are the following:

1. Interference with the vehicle radiator area.
2. Restricted forward vision for the star tracker (the side vision is excellent).
3. Close proximity to the RCS motors and their effluents.
4. Obstruction of the articulating boom access to the experiment airlock.

It should be noted that if the attitude reference system is moved to the rear of the mounting structure, it is possible to get excellent vision angles for both aft and side views. However, in this location, the attitude reference system is more remote from the photography equipment and is more difficult to maintain, since it cannot project into the pressurized area.

The concept of locating the sensor along the side is distinctly feasible and is considered one of the preferred configurations.

6.2.2.2 Configuration II--Sensors in Front of MORL

The concept is noted in Figure 6-18. The figure shows the mounting structure located in the dock port. The major advantages of this installation are the following:

1. Noninterference with the radiator area, stowed spacecraft, solar cell panels, articulating booms, and RCS engines.
2. Close proximity to the hangar/test area for ready checkout and observation after assembly.

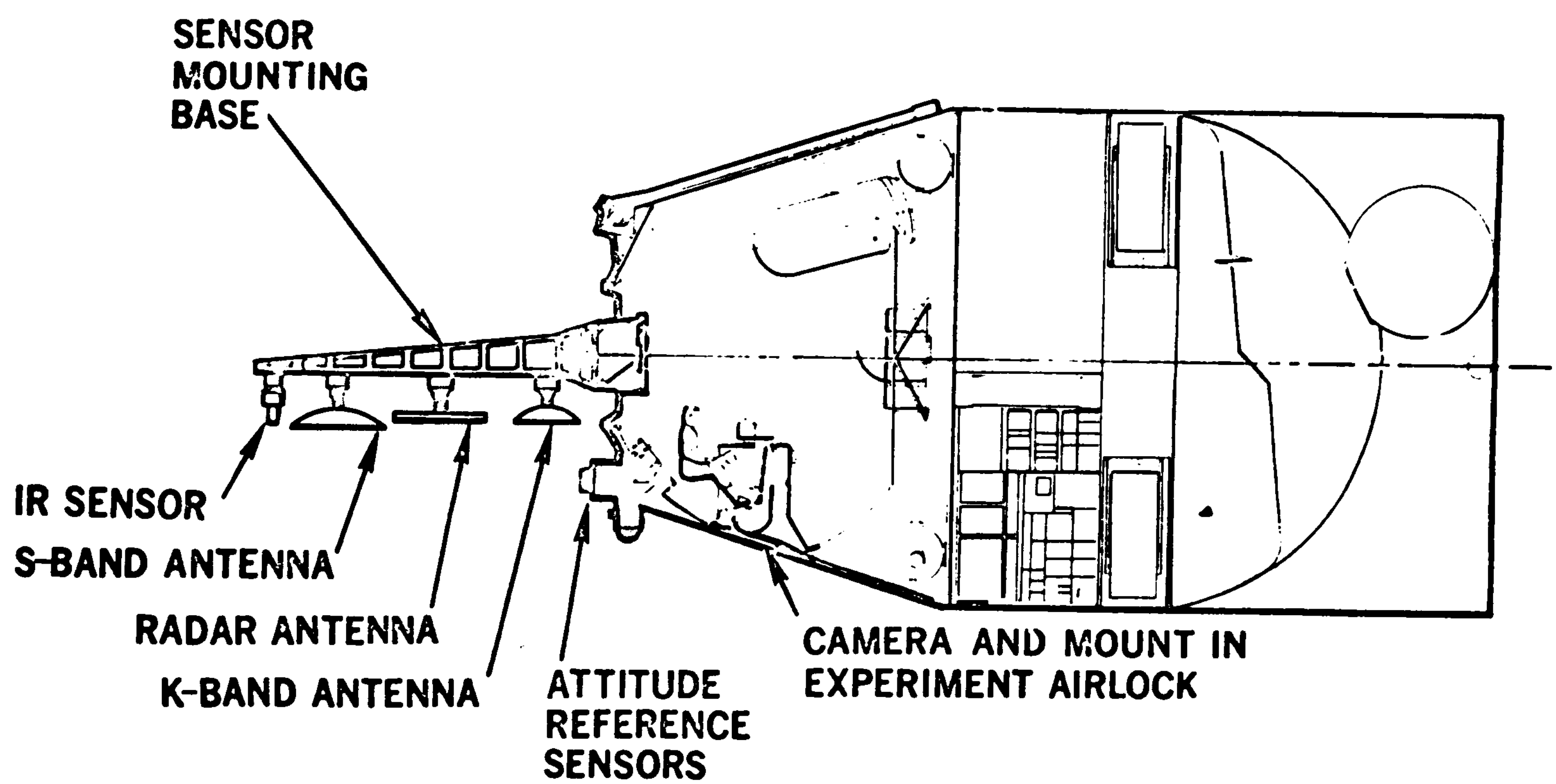


Figure 6-18. Configuration II - - Sensors Forward

The major disadvantages are the following:

1. Since it is a cantilevered system mounted in dock port it is not as rigid or stable as Configuration II or III, and it must be removed for incoming logistics vehicles or for cargo module manipulation.
2. Location of the attitude reference system sensors is difficult. If the sensors are mounted on the upper region of the MORL nose, the star trackers have excellent visibility, but the horizon sensors are obstructed by both the sensor structure and the vehicle. If the sensor is mounted on the lower portion of the nose, the horizon sensors have excellent visibility, but the star-tracker visibility in the direction forward and up is obstructed by the sensor platform. If the sensors are mounted to either side of the platform, the star-trackers have excellent visibility, but the horizon sensor visibility is obstructed in the aft direction by the MORL body or by stowed cargo modules.
3. The power cables and wave guides are long.

This concept appears to be one of the best from the standpoint of experiment sensor vision or potential interferences from other vehicle systems, but the operational problem of moving the mounting structures for each incoming spacecraft and cargo module manipulation offsets these advantages. Should a different docking system be incorporated whereby, the mounting structure need not be moved, this configuration would merit further study, as it appears that the problem associated with the attitude reference system location can be solved through further analysis.

6.2.2.3 Configuration III--Sensors Mounted on Nose

The nose configuration is shown in Figure 6-19. It shows the mounting structure moved from the side to the nose of the MORL, and it is similar to the first concept. The configuration retains most of the advantages of the first concept and presents the following advantages in addition:

1. Noninterference with the radiator area.
2. Removed from the RCS motors.
3. Permits access to the ARS equipment from the hangar/test area.

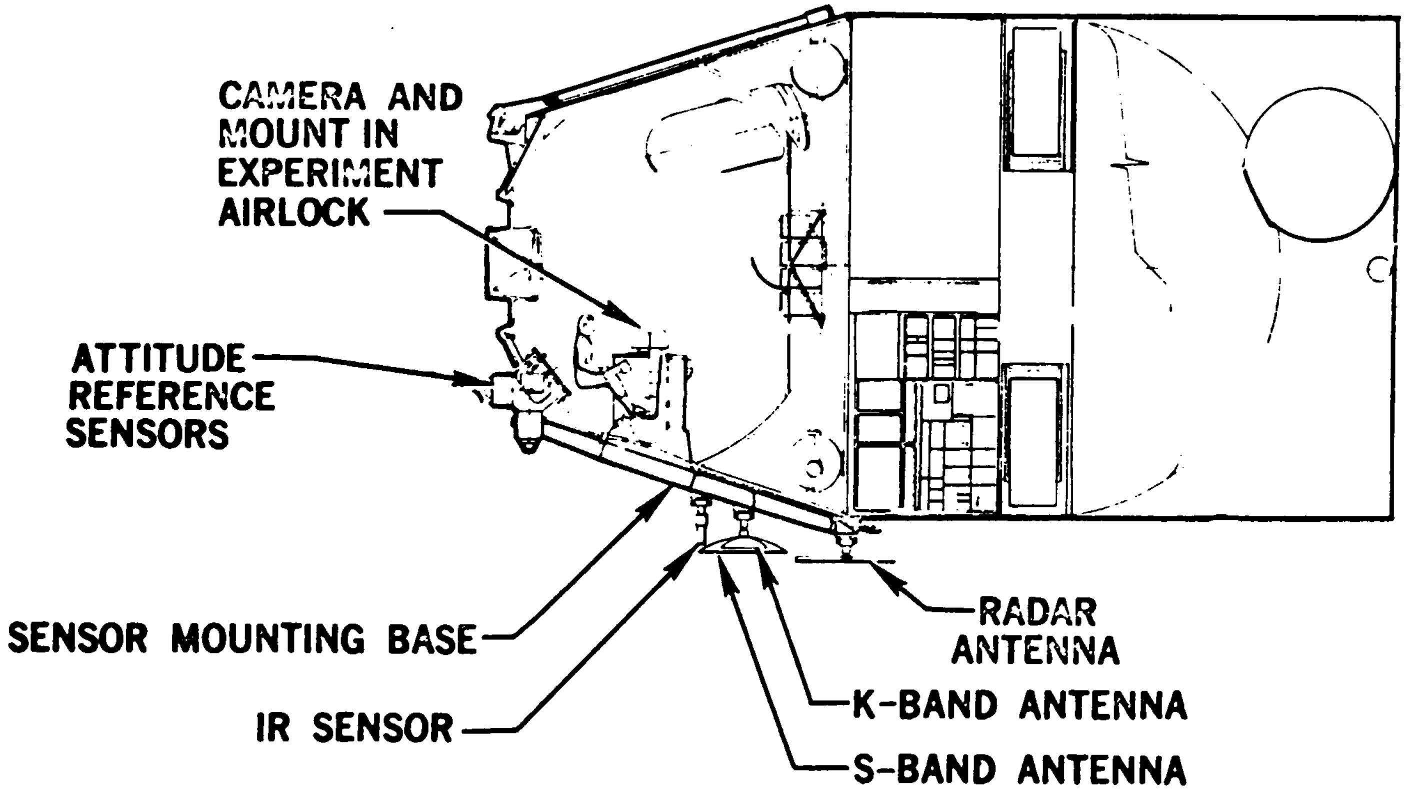


Figure 6-19. Configuration III - - Sensors on Nose

The major disadvantages are the following:

1. The attitude reference sensor visibility is somewhat restricted: for the aft horizon sensor by the experiment antennas; for the side-looking star trackers by the stowed logistics cargo modules; and for the star tracker located in the forward and up direction by a cargo module in the dock port. Since the normal condition of the MORL does not have all stowed positions filled, the vision angles may be satisfactory provided the proper stars are chosen within the star-tracker fields of view.
2. The configuration is somewhat restricted from the standpoint of experiment sensor growth because large size antennas (30 ft or more in diam) would interfere with the ARS field of view.
3. The forward articulating boom projects into the sensor fields of view. However, it is felt that this is an operating condition that can be relieved with suitable experiment scheduling.

6.2.2.4 Configuration IV--Sensor on Rear of MORL

Figure 6-20 shows a transverse mounting beam rigidly attached to the aft face of the MORL. It contains all Earth-centered sensors and the attitude reference sensor installation.

The major advantages of this concept are the following:

1. A rigid attachment to the MORL support structure.
2. Ample growth space for larger sensor equipment and uncongested sensor installation.
3. Sensors are clear of the vehicle radiator area.
4. Sensors are clear of the logistic cargo modules and articulating booms.
5. Excellent vision field for the attitude reference star tracker, the horizon sensors, and for the experiment sensors.

The installation has the following disadvantages:

1. The attitude reference sensors are located in an unpressurized area making maintenance difficult.
2. The ARS is remote from the photography experiment.
3. Optical alignment of the sensors is difficult.
4. The location is in close proximity to the RCS motors and their effluents.
5. The cable and rf waveguides are relatively long.

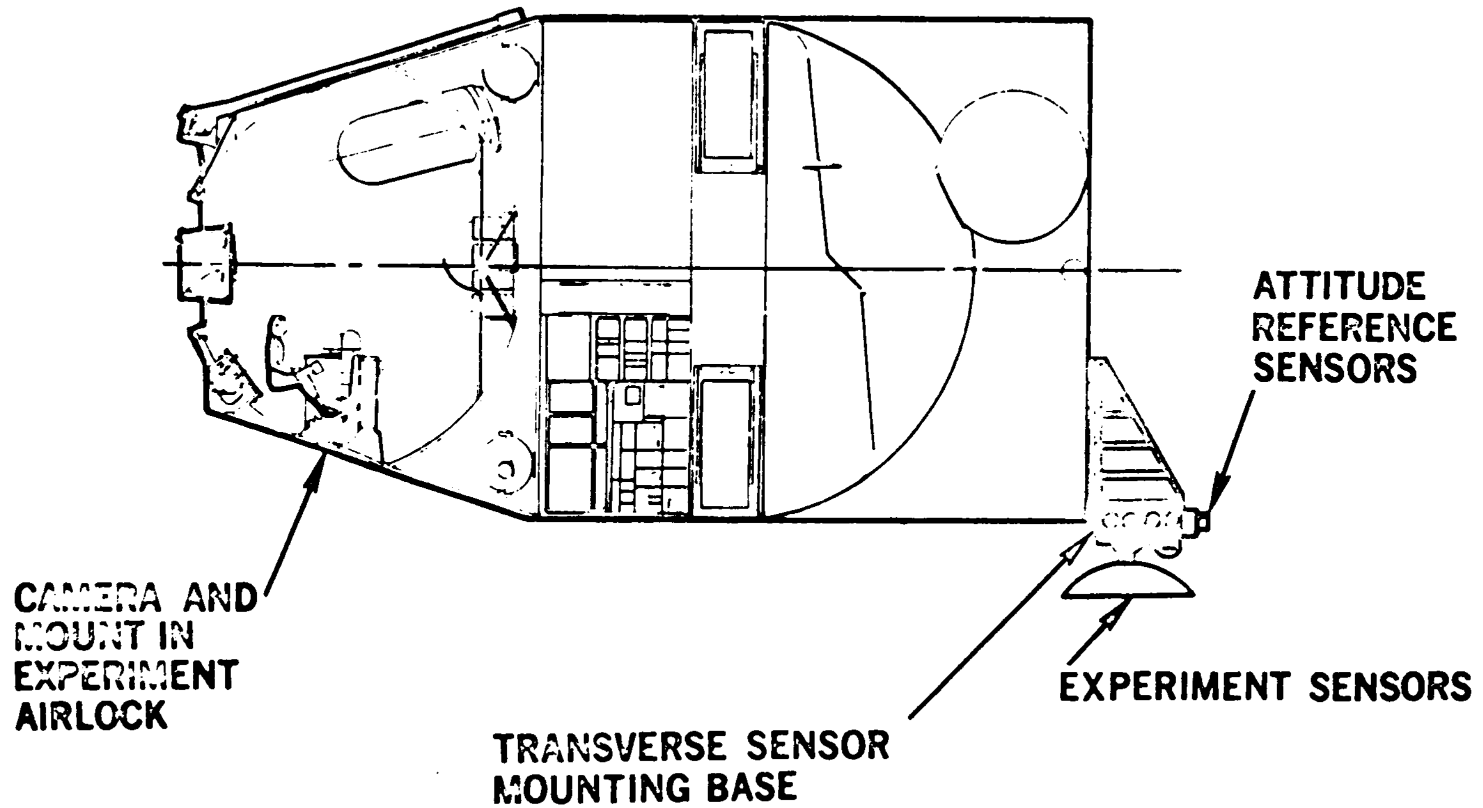


Figure 6-20. Configuration IV - - Sensors Aft

6.2.3 Configuration Selected

The concept best satisfying the requirements of the ARS and experimental sensors with a minimum of disadvantages was Configuration III--Sensors on Nose. The advantage of accessibility to the ARS for maintenance and optical alignment is perhaps the most important factor. The problems of restricted look angles for the ARS sensors can probably be solved through detailed design.

6.2.4 Recommended-Follow on Studies

This analysis of integrating the experiments chosen for the 48-hour study has brought out certain areas which require additional investigation. They are the following:

1. Investigation of the optical and mechanical alignment problems associated with multiple boresighted experiment sensors.
2. Investigation of methods to decrease the front-end congestion of spacecraft and cargo modules, both stowed and unstowed, of experiment sensors, of the articulating boom and cargo stowage arms, and of equipment mounted in, or transferred through, the experiment airlock.
3. Investigation of alternate vehicle attitudes, such as nose or tail-down, for Earth-centered experimentation.

Section 7
SUBSYSTEM ACCOMMODATION

The requirements imposed by the experiments chosen for the 48-hour study were individually reviewed and compared to the capabilities of the baseline subsystems to accommodate them. Upon completion of the time-line schedule of crew activities, a second review was accomplished to ensure that conflicting requirements were not present.

Of the five major subsystems on board the MORL, two exhibited significant limitations in their baseline design concept. Furthermore, these limitations, although precipitated by the requirements contained in this analysis, appear to be present for meeting those requirements imposed by the broad spectrum of experiments represented by the Experiment Plan. Therefore, they were pursued sufficiently to obtain firm recommendations for further analysis leading to changes in the baseline system.

7.1 ENVIRONMENTAL CONTROL/LIFE SUPPORT

7.1.1 Summary of Experimental Requirements

The general requirements for a livable atmosphere in the compartments are imposed by the experiments on the EC/LS subsystem. Since this is the normal function of the EC/LS subsystem, no additional demands can be identified. However, a specific requirement is shown below:

Item	Conditions	Requirements
Magnetic tapes	Storage and operation	40 to 60% Relative humidity

7.1.2 Discussion and Analysis

An examination of the requirements for the storage and operation of the magnetic tapes for storing the experimental data generated, showed that the capability of the atmospheric purification subsystem was marginal. The laboratory atmospheric design conditions are as follows:

Temperature: $70^{\circ}F \pm 5^{\circ}F$

Relative humidity (RH): 50% ± 20%

This requirement was reviewed with a manufacturer of magnetic tape. During the discussion it was learned that it is only the coincidence of temperature and relative humidity extremes that affect tape operation. A combination of high humidity and high temperature cause head wear and tape stretching, while low humidity and low temperature cause unwinding problems.

During normal operation, the MORL atmosphere will have a RH of 30 to 50% while the temperature will approximately be $70^{\circ}F$. These conditions were selected, because they allow a more optimum subsystem and because, due to the nature of convective cooling in zero-g environment, a lower RH increases the comfort of the crew. These broad ranges of temperature and humidity are stated for design purposes because of unusual conditions, for example, a 9-man crew at high metabolic rates where the RH could reach the extreme limits. However, the frequency of these occurrences is low and so transient (a period of a few hours at most) that they would not affect tape operation. Therefore, the baseline EC/LS subsystem is considered to be satisfactory to accommodate these requirements.

7.1.3 Additional Provisions or Modifications Required

No additional provisions or modifications are required.

7.1.4 Recommended Follow-on Studies

No additional follow-on studies are required.

7.2 STABILIZATION AND CONTROL

7.2.1 Summary of Experimental Requirements

Four of the experiments selected for inclusion in the 48-hour study have a major impact on the stabilization and control system. Requirements imposed by the remaining experiments are considered to be of negligible importance in terms of their interface with the SCS.

These experiments, selected from the areas of oceanography, are as follows:

No.	Title
AP-252	Performance Evaluation of Final Radar Equipment
AP-255	Performance Evaluation of Cameras
AP-256	Performance Evaluation of Microwave Radiometer
AP-257	Performance Evaluation of Infrared Radiometer

The requirements for these experiments are summarized in Table 7-1.

Since each of these experiments involves acquisition and tracking of an Earth-surface target, the belly down orientation is assumed. Because of the tracking requirement, each experiment sensor is equipped with its own gimbals. These gimbals permit the sensors to be slewed to maintain the target within the required field of view.

All experiments require a pointing accuracy of $\pm 0.1^{\circ}$. The maximum tracking rate of 1.2°/sec is required for all experiments and assumes a target which passes directly under the laboratory at 200 nmi. Since the actual data collection time for each of the experiments is short (on the order of milliseconds), the requirements for vehicle rate stabilization are not severe (stabilization rates of as much as 1°/sec can be tolerated and contribute less error than rates caused by vehicle orbit velocity).

With the exception of the radar experiment, the navigation requirements are not severe. This problem is further discussed in the following section.

7.2.2 Discussion and Analysis

7.2.2.1 Pointing Accuracy

Normally, the laboratory's stabilization and control system is capable of maintaining alignment of the vehicle axes with respect to an Earth-centered reference (such as belly down) to within $\pm 0.5^{\circ}$.

Table 7-1

SUMMARY OF EXPERIMENTAL REQUIREMENTS -- SCS

Experiment Definition	Orientation	Pointing Accuracy	Field of View	Rate	Navigation	Duty Cycle	Integral Gimbals	Manual or Automatic Control
AP-252 Radar	Belly down	± 0.1° accuracy* ± 0.3°/hr drift*	± 50° azimuth ± 30° elevation	1° sec instantaneous stability** 1.2°/sec tracking rate	± 1/4 ft differential altitude* time accuracy ± 0.3 - 0.5 nmi position accuracy Correlate with surface	5 - 20 min. cycles in 48 hr period*	Yes*	Programmer control* Tie-in to laboratory computer possible**
AP-255 Photography	Belly down	± 0.1° accuracy* ± 0.3°/hr drift*	± 8° to 10° about vertical*	± 1°/sec instantaneous stability** 1.2°/sec tracking rate	Time accuracy ± 0.1 sec* Correlate with surface	Exposure time as high as 1/10,000 sec 2,400 frames	Yes*	Programmer control* Tie-in to laboratory computer possible**
AP-256 Two-frequency microwave radiometry	Belly down	± 0.1° accuracy* ± 0.3°/hr drift*	Assume same gimbal angles as radar	± 1°/sec instantaneous stability** 1.2°/sec tracking rate	± 0.3 - 0.5 nmi** Time accuracy ± 0.1 sec** Correlate with surface	1.25 hr in 48 hr*	Yes*	Programmer control* Tie-in to laboratory computer possible**
AP-257 Infrared radiometry	Belly down	± 0.1° accuracy* ± 0.3°/hr drift*	1° instantaneous assume same gimbal angles as radar	± 1°/sec instantaneous stability** 1.2°/sec tracking rate	± 0.3 - 0.5 nmi** Time accuracy ± 0.1 sec** Correlate with surface	2.5 hr in 48 hr*	Yes*	Programmer control* Tie-in to laboratory computer possible**

NOTE:

* = Specified
** = Estimated

This baseline belly down mode, implemented with a horizon sensor and gyrocompass for attitude sensing, does not have the capability of providing the required 0.1° and the star tracker-inertial reference system must be used. The star-tracker inertial reference provides attitude sensing accuracy of 0.01° under ideal conditions and, when used to drive the control actuators, provides vehicle stabilization to approximately $\pm 0.1^{\circ}$.

This latter capability of $\pm 0.1^{\circ}$ is adequate for the four experiments except that this pointing accuracy must be maintained while tracking fixed target points on the Earth's surface. The control system is thus required to provide commands to the experiment gimbal drives with sufficient accuracy to maintain the overall error to within $\pm 0.1^{\circ}$.

7.2.2.2 Rate Control

Rate control involves stabilization of the experiment sensor with respect to a reference direction which may be either fixed or rotating in inertial space. For the four Earth-surface experiments, the target is moving relative to the laboratory, and slewing or tracking with the experiment sensor is required.

The instantaneous rate (relative rate between target and experiment line of sight) requirements imposed by the experiments are easily met. The instantaneous rates imposed on the vehicle by crew motion and other transient disturbances are expected to rarely exceed 0.06°/sec. By restricting crew motion it may be possible to maintain vehicle transient-induced rates to less than 0.005°/sec.

However, slewing rates will be on the order of 1.2°/sec during tracking and may be higher during target acquisition. Rates of this magnitude may be applied to the vehicle with the reaction control system (RCS) gas jets. However, the propellant requirements, on the order of 12 lb/horizon-to-horizon tracking event, are too high to permit recommendation of this mode for normal uses. Moreover, since each of the four experiments is equipped with its own gimbals, the entire laboratory does not have to be used as a slewing platform.

7.2.2.3 System Operation

The prime SCS procedure performed in support of each of the four experiments, following orientation of the laboratory to the normal belly down mode, is to first check the mechanical alignment of the star tracker-inertial reference system (IRS) and the experiment package sensor. This is done by on-board autocollimators, optical wedges, and optical flats mounted on the sensor packages. Optical flats must be provided on the experiment sensors to check the alignment.

Figure 7-1 shows the equipment and data flow in the experiment mode. Once the mechanical alignment has been established and the electrical nulling/biasing adjustments completed, vehicle coarse attitude information, obtained from horizon sensing and gyro compassing, is inserted by the SCS control console into the data processing computer (DPC). The DPC, with this coarse attitude information and precise orbit parameters (vehicle position, velocity, and time) received through the Earth's communication link, determines what are the most desirable stars available for sighting. The DPC then computes the required star-tracker inner and outer gimbal angles based upon the presently assumed attitude. Since vehicle attitude is known to within 0.5°, these gimbal angles are sufficiently accurate to bring the stars into the 1° fields of view of the star trackers. The trackers are then commanded to these computed gimbal angles.

Once the stars come within the fields of view of the tracker telescopes, the trackers are switched to a closed-loop tracking mode, and their boresights are zeroed in on the line of sight of each selected star. The tracker's actual inner-and outer-gimbal angles are then transmitted to the DPC which generates the desired inertial reference commands and transmits them to the IRS. These command signals are used to update the IRS attitude reference computation.

The single-axis inertial platforms are then switched in and provide the inertial reference for the MORL. In this case, the reference coordinates (a rotating inertial set and an orbit rate correction computed on the ground or

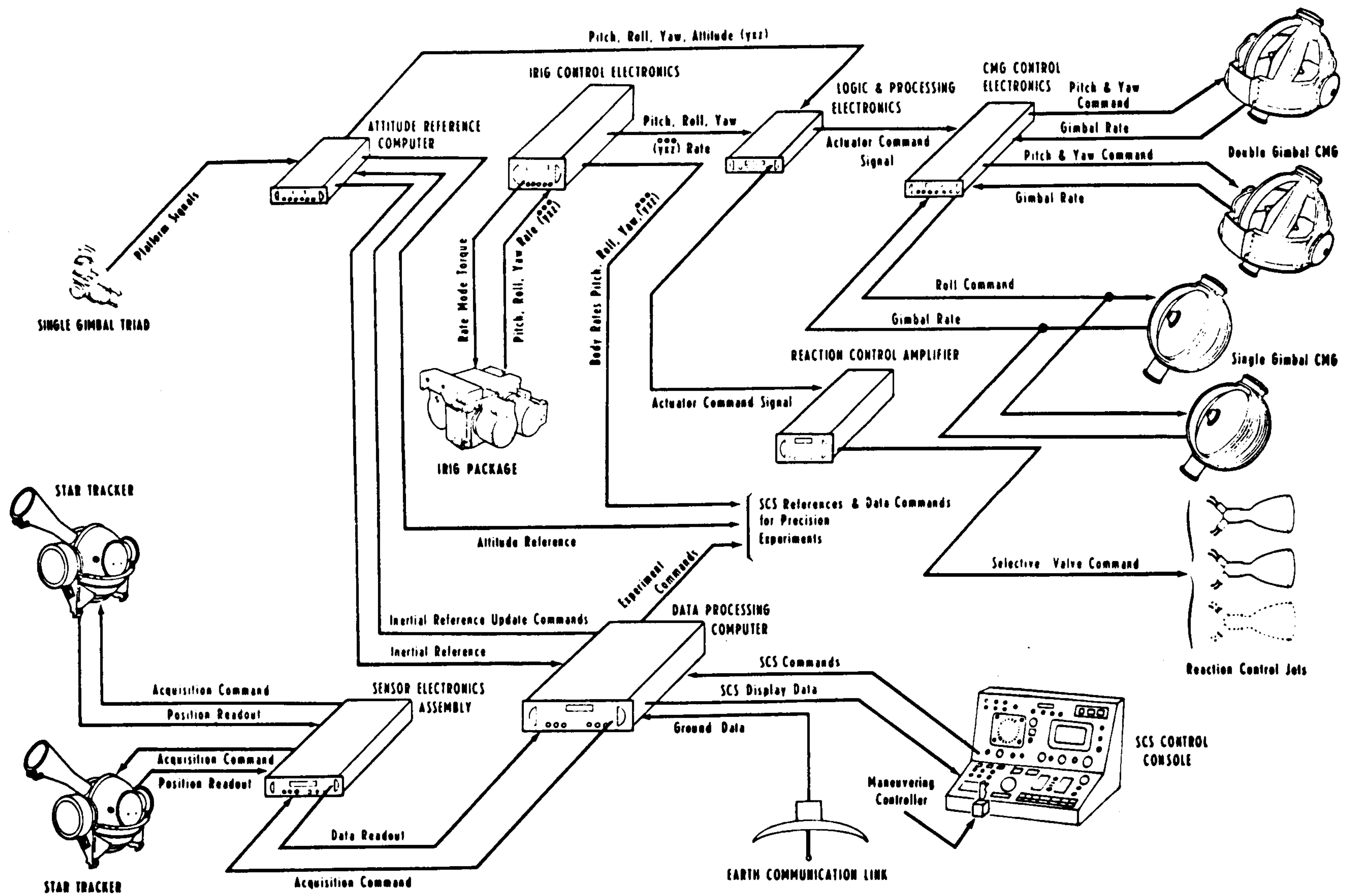


Figure 7-1. SCS Equipment and Data Flow in the Experiment Mode

in the DPC) must be applied to the inertial reference computation. Vehicle pitch rate must equal orbit angular rate to maintain the vehicle fixed with the rotating inertial reference set of coordinates.

For these experiments with an accuracy of 0.1°, the IRS maintains the vehicle attitude for approximately one complete orbit (drift rate 0.05°/hour), and the star trackers update the IRS once per orbit. The updating should be phased so that experiment data are taken as shortly after the updating as practical. For the four experiments detailed, data acquisition time phasing is such that this procedure can be readily carried out.

The following sequence summarizes operation in the experiment mode:

1. The IRS and experiment sensors are aligned.
2. The laboratory is operated belly down with coarse alignment provided by the horizon sensor and gyrocompassing using the inertial rate integrating gyro (IRIG) package.
3. The DPC supplies coarse pointing commands to the star trackers.
4. The star trackers supply fine alignment commands to the inertial platforms through the attitude reference computer.
5. The attitude reference computer supplies inertial reference information to the DPC which supplies pointing commands to the experiments.

7.2.3 Additional Provisions or Modifications Required

The baseline system can functionally accommodate the four detailed experiments; however, because of the pointing accuracies required, the mechanical alignment of the present baseline sensing elements on the vehicle cannot be maintained to sufficient accuracy to ensure meeting the 0.1° pointing requirement. To provide the accuracy for these four experiments and to improve the SCS accommodation potential for all the other precision pointing experiments, it is necessary to mechanically integrate the sensors and to provide space to accommodate a rigid mounting plate, or attitude reference base. This base should be located on the underside of the Laboratory (along the -Y-axis) and should extend forward to the nose of the MORL. This will allow mounting of the star trackers looking essentially out the +X-axis (it also provides a rigid mount for the sun sensors), and the horizon sensor heads looking essentially out the -Y-axis. The inertial reference system would be mounted in close proximity to the star and horizon sensors and provisions would be made for mounting various precision experiment sensors on the attitude reference base (ARB). Because of the many experiments which require sensor mounting on the ARB, it is probably desirable to provide several common (universal) mounting pads on the base. The precision experiment sensors would then be stored on board the Laboratory until required for use when they would be mounted, with lapped mounting surfaces to provide accurate location, on the ARB. Fine alignment would be checked by the on-board autocollimators, optical wedges, and optical flats mounted on the IRS, and the SCS and experiment sensors.

7.2.4 Recommended Follow-on Studies

The level of SCS and experiment definition used to make this accommodation assessment is not detailed enough to point out more than the most obvious incompatibilities. While this is adequate to prove the concepts, it does not prove that the performance requirements imposed by experiments, and expected to be provided by the laboratory system, can actually be met.

The term laboratory system, rather than SCS, is used because the ground stations, the communications link, the data management system, the navigation system, the stabilization and control system, the mechanical and structural interface, the environmental control system and the crew members are also involved in experimental operations. All contribute to determining the overall experiment performance and the cost of returning the experimental data.

The experimental operations will have to be streamlined as much as possible to provide maximum data return per unit of operating time and to ensure that experimental data are obtained at a reasonable cost. In order that all potential error sources are evaluated to ensure accuracy and that sufficient performance margin and methods of error compensation are provided to accomplish the foregoing objectives, the following studies are recommended:

1. Experiment-Control Interface--The perturbation caused by integrating a few selected experiments was investigated during the 48-hour study. It is recommended that this study be expanded to further

define the requirements imposed by experiments and to determine which requirements recur sufficiently to warrant a change in the control-experiment interface or the total vehicle-experiment interface.

As currently defined, each experiment with complex control requirements is equipped with its own control panel, event sequencer, and gimbal mechanism for dynamic isolation. Sufficient functional commonality between experiments probably exists to justify the development of a universal mounting fixture and control interface. By taking advantage of this commonality, the following may be accomplished:

A. Reduce the experiment equipment quantity and, therefore, payload weight.

B. Reduce the installation and operating time for each experiment by applying the same procedures to many experiments.

C. Reduce the cost of experiment development and integration.

These potential advantages warrant a study to determine the degree of commonality that exists between experiments and to determine if experiments can be modified to meet a least-common-denominator, control-experiment interface. The requirements, thus defined, would be used to develop the following overall installation interface:

- Mounting and clearance dimensions.
- Temperature control provisions.
- Gimbal positioning and rate control criteria.
- Electrical power and signal transfer method.
- Control console provisions for checkout, event sequencing, generation of attitude or rate commands, output data routing, and so forth.

2. Experiment Alignment--The establishment and maintenance of adequate alignment accuracy between the experiment and the laboratory's attitude reference system is an experiment-controls interface that requires extensive analysis. In some cases, experiments must be pointed toward an objective with at least an accuracy of 0.01° with respect to the on-board reference which is aligned to the same order of accuracy. This problem, difficult to solve in a ground-based laboratory, is complicated by installation of the experiment in the orbital environment, several feet from the reference source, and accomplishment of the alignment with a minimum expenditure of crew time.

   Although this problem is discussed in the current study phase, the study should be extended (1) to define the alignment scheme in more detail; (2) to evaluate perturbations resulting from temperature differential, pressure differential, and vibration effects; and (3) to conduct error analyses to determine what accuracies can be expected as a function of the alignment technique and procedure chosen.

3. Experiment Performance Evaluation--Since the experiment-control functional interface is defined, and the error contributed by misalignment is known, overall performance of the experiment-control system combination should be evaluated. This study would define several basic experiments requiring sensor pointing and tracking with and without the aid of information derived from the target objective.

   The experiment control requirements would be defined in terms of the discrete and variable functions to be generated and in terms of the accuracy of data and resolutions to be measured and processed. Computational requirements for the central data computer and the control data computer would be developed, and the effects of varying the experiment sensor control laws would be examined.

   Simulation of the complete system, including computers, sensors, control laws, and error sources, would provide a reasonable evaluation of the experiment performance. Based on the results of this simulation testing, the adequacy of each major element in the total experiment-control system complex can be evaluated, and the need for initiating development activity can be defined.

7.3 COMMUNICATIONS AND TELEMETRY

7.3.1 Summary of Experimental Requirements

The following sections summarize experimental requirements.

7.3.1.1 Oceanographic Experiments

Table 7-2 summarizes the requirements for handling data that are imposed on the MORL communications/telemetry system by the oceanographic experiments. Word lengths and sample rates necessary to meet the accuracy requirements and dynamic rates are listed below:

Radar range:	8 bits at 1,000 samples/sec
Microwave radiometer temperature:	10 bits at 10 samples/sec
IR radiometer temperature:	10 bits at 10 samples/sec

In addition, sensor positioning and sequencing up-link command requirements are as follows:

Sensor attitude:	10 words of 11 bits each
Time-to-go-to start/stop:	8 words of 18 bits each

Moreover, internal communication/telemetry subsystem command verification will require echo checks. These echo checks are indicated by Items 4 through 13 in Table 7-2. Table 7-3 is an orbit-by-orbit breakdown of the data-sampling requirements of the sea-state and sea-temperature portions of the oceanographic experiment. The table indicates elapsed time and total data samples made since a previous ground-site contact. This information was derived by placing the time-line analysis experiments in juxtaposition to a similar analysis of the baseline (Cape Kennedy, Corpus Christi) ground-coverage profile. The data of Table 7-3 were then further reduced (Table 7-4) to indicate the total number of bits of data collected (samples times bits/word) between ground contact occurrences. To render this information useful for baseline system comparison, it was assumed that the data of Table 7-3 could be restructured in the fixed format of the baseline data-acquisition system (DAS). The two columns to the right of Table 7-4 were derived by pursuing this assumption. These data represent the equivalent number of baseline DAS words required to retain the information contained in the 8-bit and 10-bit data samples of Table 7-3. It should be noted that the data in Table 7-4 do not include header data, tag, label data, reformat program counter, or address field information. Data of this type would be necessary for ground decommutation and, later, identification. Hence, the data in Table 7-4 are considered conservative.

7.3.1.2 Cosmic Dust Measurements

This experiment utilizes eight sounding boards with microphones and eight lucite or glass surfaces in conjunction with photomultiplier tubes to detect momentum (and possibly mass) of incident particles. The analog output of each of these 16 sensors is a series of randomly spaced pulses occurring at the estimated average rate of 3/min. and peak rate of 5/sec. Measurement of pulse amplitude and pulse width is desired. It is assumed, for purposes of this analysis, that pulses are approximately of a 10-msec duration. If these analog outputs were to be monitored by a time-multiplex system, a continuous sampling rate of 2,000 samples/sec would be required for each of the 16 channels to define the pulse widths within a 5% accuracy. Data are to be taken continuously.

Table 7-2

INSTRUMENTATION REQUIREMENTS -- MORL OCEANOGRAPHIC EXPERIMENT (page 1 of 2)

Item	Variable to be Serviced	Scale Range of Variables	Sample Rate of Variables	Desired Accuracy	Bits/ Word
1	Radar range	0 to 60 ft	1,000 sample/sec	±0.5 ft	8
2	μ-Wave radiometer sea temperature	-5°C to +35°C	10 sample/sec	±0.1°C	10
3	IR radiometer sea temperature	-5°C to +35°C	10 sample/sec	±0.1°C	10
4	Radar antenna η position ∠	±90°	*	±0.1°	11
5	Radar antenna ϵ position ∠	±90°	*	±0.1°	11
6	μ-Wave K antenna position ∠	±90°	*	±0.1°	11
7	μ-Wave K antenna position ∠	±90°	*	±0.1°	11
8	μ-Wave X antenna η position ∠	±90°	*	±0.1°	11
9	μ-Wave X antenna ϵ position ∠	±90°	*	±0.1°	11
10	IR sensor η position ∠	±90°	*	±0.1°	11
11	IR sensor ϵ position ∠	±90°	*	±0.1°	11
12	Camera η position ∠	-10° to +10° look ∠ = 8°	*	±0.1°	6
13	Camera ϵ position ∠	-10° to +10° look ∠ = 8°	*	±0.1°	6
14	Radar antenna η command ∠	±90°	**	0.1°	11
15	Radar antenna ϵ command ∠	±90°	**	0.1°	11

*Echo checks made onboard required for C/T subsystem to verify appropriate sensor reaction to digital commands. Will require on-board sampling, storage, formatting, and failure alarm test.

**Up-link digital commands. Require decoding, storage, and distribution.

Table 7-2 (page 2 of 2)

Item	Variable to be Serviced	Scale Range of Variables	Sample Rate of Variables	Desired Accuracy	Bits/ Word
16	μ-Wave K antenna η command $\angle$	$\pm 90^{\circ}$	**	0.1°	11
17	μ-Wave K antenna ϵ command $\angle$	$\pm 90^{\circ}$	**	0.1°	11
18	μ-Wave X antenna η command $\angle$	$\pm 90^{\circ}$	**	0.1°	11
19	μ-Wave X antenna ϵ command $\angle$	$\pm 90^{\circ}$	**	0.1°	11
20	IR sensor η command $\angle$	$\pm 90^{\circ}$	**	0.1°	11
21	IR sensor ϵ command $\angle$	$\pm 90^{\circ}$	**	0.1°	11
22	Camera η command $\angle$	$\pm 10^{\circ}$	**	0.1°	11
23	Camera ϵ command $\angle$	$\pm 10^{\circ}$	**	0.1°	11
24	TTG to start radar command	0 to 200 min.	**	1 msec	18
25	TTG to stop radar	0 to 200 min.	**	1 msec	18
26	TTG to start μ-wave radiometer	0 to 200 min.	**	1 msec	18
28	TTG to stop μ-wave radiometer	0 to 200 min.	**	1 msec	18
29	TTG to start IR radiometer	0 to 200 min.	**	1 msec	18
30	TTG to stop IR radiometer	0 to 200 min.	**	1 msec	18
30	TTG to start camera	0 to 200 min.	**	1 msec	18
31	TTG to stop camera	0 to 200 min.	**	1 msec	18

**Up-link digital commands. Require decoding, storage, and distribution.

Table 7-3

DATA COLLECTION AND STORAGE REQUIREMENTS AS A FUNCTION OF ORBIT NUMBER DURING 48-HOUR PERIOD -- OCEANOGRAPHIC EXPERIMENTS

	Radar (252) 8 Bits/Word 1,000 Words/sec		IR Radiometer (257) 10 Bits/Word 10 Words/sec		Microwave Radiometer (256) 10 Bits/Word 10 Words/sec		
Ground Contact No.	Sample Time Since Previous Contact (min.)	Samples Since Previous Contact (Words x 10^3)	Sample Time Since Previous Contact (min.)	Samples Since Previous Contact (Words x 10^3)	Sample Time Since Previous Contact (min.)	Samples Since Previous Contact (Words x 10^3)	Words/Orbit x 10^3
1							
2					20	12	12
3			20	12	40	24	36
4			18	10.8	15	9	19.8
5			18	10.8			10.8
6			27	16.2			16.2
7	19	1,140	19	11.4			1,151.4
8	32	1,920	17	10.2			1,930.2
9	18	1,080					1,080
10	16	960	16	9.6			969.6
*None	15	900	15	9			909
Totals	100	6,000	150	90	75	45	6,135

NOTE:

* Indicates data collected after last ground contact during 48-hour period analyzed.

Table 7-4

DATA COLLECTED BETWEEN GROUND CONTACT OCCURRENCES

Ground Contact No.	Total Bits Since Previous Contact $\times 10^6$	Oceanographic Experiment Data Normalized to 6-Bit Baseline Words	
		1,000 Samples/sec $\times 10^6$	10 Samples/sec $\times 10^6$
1			
2	0.120		0.02
3	0.360		0.06*
4	0.198		0.033
5	0.108		0.018
6	0.162		0.027
7	9.234	1.539	0.019
8	15.462	2.577*	0.017
9	8.64	1.44	
10	7.776	1.296	0.016
None	7.29	1.215	0.015
Totals	49.350	8.067	0.225

*Worst-case data loads selected for system accommodation comparison, Table 7-5.

7.3.1.3 High-Energy Particulate Radiation on Materials

This experiment utilizes four sets of samples of materials (three on the laboratory and one reference set on the ground) which are observed and analyzed for changes that can be attributed to high-energy particulate radiation. Data are acquired and recorded in a notebook.

7.3.1.4 Solar Absorptivity and Thermal Emissivity of Materials

In this experiment, calorimetric measurement techniques and reflectance measurements are used to determine the solar absorptivity and thermal emissivity of material that has been exposed to the space environment. Changes in materials that affect the two properties of interest are determined by visual observations and chemical analyses. The results of these observations and analyses are recorded in a notebook. The electrical outputs of the measuring equipment require two telemetry channels with an output capability of 1 sample/sec for 30 min.

7.3.1.5 Space Vehicle Thermal Equilibrium

In this experiment, 25 thermocouples are placed at appropriate locations in MORL to survey the temperature profile of the vehicle. The data obtained are used in thermal equilibrium studies. Each channel is sampled at the rate of 1/min.

7.3.1.6 High-Frequency Communication

In this experiment, high-frequency receiving equipment and associated recording and analysis equipment were used to make ground-to-space oblique sounding and noise measurements. Data for telemetry consist of 1 analog and 4 digital sources (the equivalent of 17 channels at a sampling rate of 1 sample/min). Pictorial data (ionographs and noise maps) are to be sent to Earth.

7.3.1.7 Fatigue Tests of Materials

Notched coupons which are exposed to the space environment are placed in a static test machine which applies low-speed cyclic loading. Tests are continued until the coupons are destructed. Data are recorded on graph paper and in notebooks. Selected information on test loads, time to fracture, and time in vacuum is to be transmitted to Earth.

7.3.1.8 Ionizing Radiation Measurements

In this experiment, the space radiation telescope (SRT) is used for measuring radiation incident upon the outside of the spacecraft. Scintillation counters, ionization counters, and sandwich spectrometers are used at four locations at 90° intervals around the laboratory to measure internal radiation. The SRT requires 25 channels of 25 samples/sec each for a period of 2 min./orbit. The other instruments require 8 channels with a sampling rate of 1 sample/sec.

7.3.1.9 Crew Performance Capabilities

Performance scores obtained during these tests must be transmitted to Earth.

7.3.1.10 Crew Performance Relationships

Each crew member spends 15 min./day dictating a diary of his space activities into a tape recorder. The data load is 1.5 hour/day of 3 kc analog data, which must be subsequently transmitted to Earth.

7.3.1.11 Retention of Skills

In this experiment, a special device controlled by computer is used to determine tracking skills, and a simple pegboard device is used to determine dexterity. No other data handling requirements are generated by the experiment.

7.3.1.12 Behavioral Measurements (Orbital and Re-entry Operations)

In this experiment, a MORL-to-ground television link and a two-way voice communication link are required so that crew members can be interviewed by an Earth observer. Operation time will average 18 min./day. The voice link should be such that it allows private conversation. Only the simulated re-entry task is scheduled to be performed during the 48-hour period.

7.3.1.13 Ventilation of Respired Gases

In this experiment, a gas chromotograph is used to indicate the presence and quantity of certain gases in an artificial atmosphere. A channel with a sample rate of 1 sample/sec is required to perform the experiment.

7.3.1.14 Biological Monitoring of all Life-Support Systems

In this experiment, manual operations are required to determine (1) water supply bacterial count, (2) air supply bacterial count, (3) air supply foreign particle count, (4) waste disposal systems bacterial counts, and (5) surface contamination at predetermined sites. This information will be recorded in a log book. There is no interface with the C/T system.

7.3.1.15 Isometric and Isotonic Force-Producing Capabilities

The pulse rate and the body temperature of crewmen under test must be monitored. On the average, data will be obtained during 0.5 hours/day. These data will be derived from the appropriate sensor in the space suit of crewmen.

7.3.2 Discussion and Analysis

In the following sections, experimental requirements are discussed and analyzed.

7.3.2.1 Oceanographic Experiments

If it is assumed that all data tabulated in Table 7-4 are to be telemetered to Earth, the worst case load is represented by entries in Columns 2 and 3 of the table which are marked with an asterisk. These figures vary widely because of the differing measurement period lengths and because of the varying elapsed times between Earth contacts as indicated by the Earth coverage analysis. As indicated, the largest 10 sample/sec. down-link load occurs on the third pass while the eighth Earth contact represents the largest of the 1,000 sample/sec data loads.

The baseline DAS capability is outlined in Table 7-5. The second column at the left indicates the number of data points which can be sampled at the subchannel rate defined in the extreme left column, as provided in the baseline mechanization. The third column indicates the effective sampling rate of the multiplexer required by the first two columns. For example, if each of 240 data points is to be sampled at the rate of 1/min., the scan rate of the multiplexer must be 4 data points sampled/sec ($240 \div 60$ sec = 4/sec). The second group of three columns represents the baseline DAS requirement as defined by the

Table 7-5

COMPARISON OF BASELINE DATA MANAGEMENT CAPABILITY AND OCEANOGRAPHIC EXPERIMENT DATA REQUIREMENTS

Data Subchannel Samples	Baseline Capability			Baseline Requirements			Available for Experiments			Required by Experiment		
Per Second	Number of Data Points	Effective Words/sec	Tape Storage Words $\times 10^6$	Number of Data Points	Effective Words/sec	Tape Storage Words $\times 10^6$	Number of Data Points	Effective Words/sec	Tape Storage Words $\times 10^6$	Number of Data Points	Effective Words/sec	Tape Storage Words $\times 10^6$
1/min.	240	4	0.24576	145	2.4	0.147456	95	1.6	0.098304	--	--	--
10/min.	90	15	0.9216	49	8	0.491520	41	7	0.43008	--	--	--
1/sec	121	121	7.43424	75	75	4.608	46	46	2.82624	--	--	--
5/sec	32	160	11.0304	19	95	5.8368	13	65	3.9936	--	--	--
Total Low rate	483	300	18.432	288	180.4	11.083776	195	119.6	7.348224	--	--	--
10/sec	--	--	--	--	--	--	--	--	--	2	2	0.06
40/sec	12	480	3.6864	1	40	0.3072	11	440	3.3792	--	--	--
120/sec	16	1,920	14.7456	16	1,920	14.7456	0	0	0	--	--	--
1,000/sec	--	--	--	--	--	--	--	--	--	1	1	2.577
Total Medium rate	28	2,400	18.432	17	1,960	15.0528	11	440	3.3792	3	3	2.637

Phase I and Phase II studies. To normalize the oceanographic experiments in terms of baseline DAS subchannel capability, the third column (Tape Storage Words x 10^6) was derived for each of the four groups. The tape parameters defined for baseline are as follows:

$$\text{Tape length} = 2,400 \text{ ft} = 28.8 \times 10^3 \text{ in.}$$

$$\text{Tape speed} = \frac{15}{32} \text{ in./sec; low-rate channel}$$

$$\text{Tape speed} = \frac{15}{4} \text{ in./sec; medium-rate channel}$$

From these parameters, the total record times can be calculated for low- and medium-rate channels of the baseline. These times are as follows:

$$\text{Low-rate channel record time} = t_L = 61.44 \times 10^3 \text{ sec}$$

$$\text{Medium-rate channel record time} = t_L = 7.68 \times 10^3 \text{ sec}$$

With this information and the effective multiplexer sample rates indicated in the second column of each group, the total tape-storage capacity for each subchannel can be readily calculated. The baseline capabilities are then reduced in Table 7-5 to the total number of words (at a given sample rate) which can be stored for transmission to Earth over the two channels available in the baseline system. This is precisely the form of the information presented in Table 7-4 for oceanographic experiment requirements.

No subchannels are provided in the baseline C/T subsystem which exactly meet the 10 sample/sec and 1,000 sample/sec sampling requirements of the oceanographic experiment. However, by judicious cross-strapping on available subchannels, the radiometer data requirements are well within the baseline capability. The radar instrumentation is totally incompatible with baseline. By assigning two addresses of the 5 sample/sec subchannel to each of the 2 radiometer outputs, these data are within the available capacity of the baseline DAS. Table 7-5 indicates an unused tape capacity of 3.99 megawords for the 5 sample/sec subchannel. In Table 7-4, the worst case data-storage requirement is 1.22 megawords. This does not seem to compromise the system. Because of the high rate at which the radar data are sampled (1,000 sample/sec), 9 addresses from the 120 sample/sec subchannel, or 25 addresses from the 40 sample/sec subchannel must be assigned. Table 7-5 clearly illustrates the impossibility of this assignment. Other equally impossible cross-strapping address assignments maybe desired.

Manual microscopic examination of photographs is required for reduction of photographic data. This precludes the possibility of central data processor analysis of this part of the experiment. This is partly caused by the extremely high resolution required, 100 lines/mm, well beyond the current technology in automatic scanning techniques, and partly by the nature of the information contained in the photograph, requiring a highly skilled experimenter for meaningful reduction. Consequently, the recommendation that all photographic data be manually processed and that hard-copy be stored is accepted without qualification.

7.3.2.2 Remaining Experiments

Of the 14 remaining experiments, 9 can readily be accommodated by the communication/telemetry (C/T) system. In some of these experiments, manually recorded data are obtained. Data of this type can be entered into the telemetry link through the typewriter and computer. In others, data are produced at rates and in quantities that can be entered directly into the telemetry system. The requirements of the other five experiments merit a more detailed analysis.

The data requirements of the cosmic dust experiment pose a problem to the C/T system. Since data are to be taken continuously, the cosmic dust experiment must be handled by the low-rate PCM system. The total sampling capacity of this system, however, is only 300 samples/sec. Clearly it cannot handle a data rate of 2,000 samples/sec from each of 16 sensors.

An alternate approach is to provide equipment with each sensor which would produce two outputs to telemetry: (1) pulse amplitude and (2) pulse width. Each of these outputs from the 16 sensors would be sampled at 5 samples/sec, the maximum expected pulse rate. If the other data required to support this experiment (6 vehicle position and attitude signals and 8 panels orientation signals) are added to the sensor output requirements, this would be 46 channels of 5-samples/sec data. The baseline low-rate PCM system provides 32 channels with a sample rate of 5 samples/sec, and only 13 of these are available for experimental data. Although this last method of data acquisition approaches much more closely the capabilities of the system, the system is still only approximately 30% responsive to the requirements.

It is concluded that the cosmic dust measurements experiment can be only partially accommodated by the baseline C/T system, and the system would have to be significantly revised to make it fully responsive.

To accommodate the data from the space vehicle thermal equilibrium experiment, it will be necessary to add a low-level multiplexer to the C/T system or to provide a multiplexer as part of the experiment equipment. A multiplexer operating at a rate of 60 samples/min. and connected to the input of one of the baseline C/T 1-sample/second channels would be more than adequate to handle the data.

The voice tape recorder required for the crew performance relationships experiment does not exist in the baseline C/T system and would either have to be added to the baseline system or included as part of the experiment equipment. The data load of 3kc for 1.5 hours/day cannot be accommodated by one of the normal vhf voice links because of insufficient ground contact time. The tape recorder could, however, be played back at a speedup ratio of 10 to 1, and the 30kc output handles through the television transmitter.

Only part of the data obtained from the ionizing radiation experiment can be accommodated. Eleven of the 25 channels of data from the SRT can be handled by 11 of the 40-sample/sec channels of the medium-rate PCM system. The requirement for 8 channels at a sampling rate of 1 sample/sec can be met by the low-rate PCM system.

The secure voice link required by the behavioral measurements is not provided by the C/T system. A voice scrambler could be added as part of the experiment equipment.

7.3.3 Additional Provisions or Modifications Required

The preceding paragraphs illustrate that the baseline C/T system cannot handle the high-rate or video data generated by the experiments selected for this analysis. One approach to the problem has been to consider that the equipment to provide this capability is part of the experiment equipment, for example, the wide-band recorders which store radar and IR data are part of the experiment equipment. Such an approach avoids the real problem of system design. In reality, the baseline system should be reconfigured to provide a wide-band data handling capability. Also, many of the requirements that are satisfied are met in a rather clumsy manner. Data are sampled at rates higher than necessary, simply because only fixed discrete sampling rates are available, or because cross-strapping of a number of channels is required to obtain a higher sampling rate not normally provided. A readily programmable multiplexer that can be brought under both manual and automatic control is required to provide data-sampling formats which are optimized to meet the changing data-sampling format requirements.

7.3.4 Recommended Follow-On Studies

A purposeful redesign of the C/T system hinges on the definition of a set of valid requirements. These requirements must include not only the number of data sources and their data rates for each experiment, but also the schedule of the experiments. This type of information has been sketchy in the past. It is, therefore, recommended that follow-on studies be conducted to derive detail data requirements imposed by the experiment plan.

A second follow-on study is recommended to investigate advance techniques of data handling for space laboratories. Prime consideration should be given to the use of adaptive data acquisition and compression techniques.

The navigation requirements imposed by the 48-hour experiments indicate that the baseline navigation technique is unsatisfactory. The primary problem is the lack of real-time updates in conjunction with the experiments. The addition of tracking sites will not materially improve the situation if ephemeris determination is performed only at IMCC. The problem revolves about the transit time for tracking and ephemeris data between IMCC and the remote site. If the baseline system is used, the experimental program would be seriously limited because the experiments would have to be conducted immediately after the initial update to ensure the required level of navigation accuracy. Therefore, an autonomous navigation system is desirable for MORL because it removes the dependence on ground tracking and permits update fixes to be taken when needed. It is recommended that an examination of this application for MORL be undertaken with the possibility of incorporating this capability into the baseline system.

7.4 PROPULSION/REACTION CONTROL

The 18 experiments impose no specific requirements on the Propulsion/ Reaction Control subsystem. Although the four oceanographic experiments impose slewing requirements on the laboratory, the propellant requirements to accomplish each maneuver with the RCS are large enough in magnitude to warrant usage of the CMG's instead. These requirements and this accommodation are discussed in Section 7.2.2.

7.5 ELECTRICAL POWER

7.5.1 Summary of Experimental Requirements

The electrical power system is required to supply all of the necessary power (quantity and quality) for the experiments and for the normal housekeeping loads. The electrical power requirements to support the on-board activities, as scheduled in the timeline analysis, were examined. The results of this analysis are shown in Figure 7-2 and the experimental power requirements in Table 7-6.

7.5.2 Discussion and Analysis

The electrical power that is available for experiments was estimated in Phase IIa to be 2,000 W. However, because of increased housekeeping requirements and because of an increase to a 15% power reserve for growth and contingencies, only 1,446 W are now available.

The electrical load profile of Figure 7-2 shows the experimental power demand for all of the experiments during the 48-hour period under study. The peak load is 1,203 W and has a duration of only approximately 10 min. The average power load is only 190 W compared to 1,446 W for the average available power, and only 13.1% for the average power utilization.

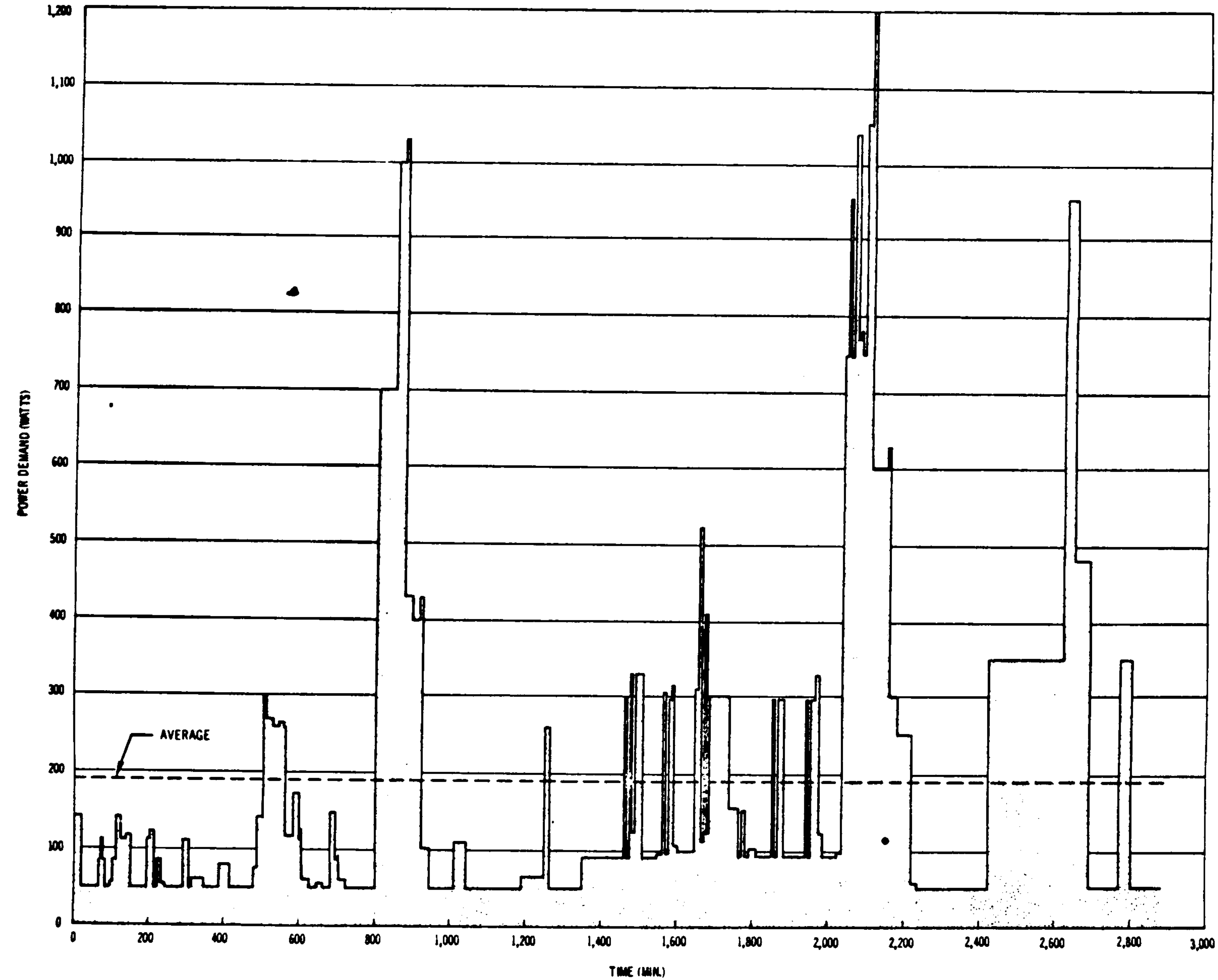


Figure 7-2. Electrical Load Profile (48-Hour Study Experiments)

Table 7-6

EXPERIMENTAL POWER REQUIREMENTS -- 48-HOUR STUDY

	Experiment	Whr/Day	
		Day 1	Day 2
252	Radar	62	976
255	Photography	99	1,753
256	Microwave radiometer	50	--
257	Infrared radiometer	72	48
IA-1	Cosmic dust measurements	600	600
IA-11	Ionizing radiation measurements	144	244
IB-23	High-energy particulate radiation	--	--
IC-15	Thermal equilibrium study	--	--
IIC-1	HF communications	233	233
IIIA-4	Force-producing capabilities in zero g	--	--
IIIA-5	Evaluation of behavioral responses (Part I)	7	--
IIIA-6	Evaluation of behavioral responses (Part II)	8	8
IIIA-7	Crew performance	67	67
IIIA-8	Retention of skills	15	15
IIIB-3	Fatigue tests of materials	--	400
IIIB-6	Solar absorptivity and thermal emissivity	--	--
IIID-16	Biological monitoring of EC/LS	1,563	1,563
IIID-17	Ventilation of respired gases	144	144
	Total:	3,064	6,051

The total power (watt-hours) required by the experiments for Day 1 and Day 2 of the 48-hour period are shown in Table 7-6 as 3,064 Whr and 6,051 Whr, respectively. The power available for experiments is 1,446 W or 34,700 Whr/day as shown in Table 7-7. Hence, the power that is consumed by the experiments is only 9% and 17.5% of the available power for Day 1 and Day 2, respectively. The peak experimental load should not, under normal operation, exceed the available power level, although the electrical power system has been designed to operate at 150% of rated power for 1 hour once each 24 hours. The peak experimental load occurs at 1,203 W and is below the 1,446 W available. It should be cautioned that the experimental power requirements do not account for conversion and regulation efficiencies. The type and quality of power required for the experiments is presently unknown. Therefore, it would be expected that the values noted in Figure 7-2 and Table 7-6 will be slightly higher than indicated.

If the conversion and regulation efficiencies are taken into account, it is estimated that more than enough power will be available at all times during the 48-hour period to operate experimental loads.

7.5.3 Additional Provision or Modifications Required

No additional provisions or modifications are required.

7.5.4 Recommended Follow-on Studies

No follow-on studies are recommended.

Table 7-7

ELECTRICAL LOAD SUMMARY -- AVERAGE WATTS

System	Unregulated 28 to 31 Vdc	Regulated 28 ±0. 5 Vdc	115/200 V, 400 cps ac
Guidance and control	25	237	98
Communication and data acquisition	153	449	--
Environmental control and life support	71	51	935
Displays and controls	285	--	--
Logistics vehicle and maintenance	789	--	49
Lighting and miscellaneous	73	--	162
Propulsion	1	--	--
Subtotal:	1,397	737	1,244
28 ±0. 5 Vdc reflected	819		
ac reflected	1,555		
Subtotal:	3,771		
Experiments	1,446		
15% reserve	783		
Total:	6,000		

Section 8
MISSION OPERATIONS AND SUPPORT

The ground systems are responsible for the support of the MORL operational and experimental requirements relative to data transfer, navigation, and mission control. Additionally, for certain of the oceanographic experiments, ground facilities are required to supply comparative data for eventual collation with the MORL-generated data.

The fundamental functions comprising the above identified areas of support are radar tracking, ephemeris (and other uplink or collation data) computation, command, telemetry data reception and handling, and voice communications.

To handle these functions, three unique ground-support facilities are required, that is, IMCC (comprised of the MOCR, RTCC, and so forth), remote sites, and the instrumented ocean areas.

8.1 SUMMARY OF REQUIREMENTS

The nature and extent of the requirements related to each of the above support functions divide logically along operational and experimental lines. Therefore, they will be considered in this manner in the following paragraphs.

The operational requirements discussed below consider only those which uniquely arise as the result of the orbit chosen for the 48-hour study (that is, 50° inclination - 200-nmi mission).

8.1.1 Operational Requirements

There are two ground support operational requirements which are particularly orbit dependent as the result of orbit influence on remote site-to-MORL contact time. These requirements are: (1) tracking (in support of the operationally required navigation accuracy), and (2) operational data telemetry dump.

To support the operational tracking for ephemeris determination (navigation update routine), three tracking opportunities and one command opportunity must be possible approximately once every day within a four-orbit span. In support of the data dump needs, the baseline remote-site network must afford at least 45 min./day contact time.

8.1.2 Experiment Requirements

The experiments considered in the 48-hour study impose the following ground support requirements:

1. Communications--Voice contact between MORL and Earth is considered essential prior to the initiation of an individual or a series of oceanographic measurements, as well as shortly after major MORL experimental operations (for example, installation of antennae) to ensure close coordination between the MORL and the crew involved with the instrumented surface areas.
2. Tracking--Ground tracking is necessary for the determination of experiment control parameters, such as start and stop times (based on an accurate knowledge of MORL ephemeris), and collation data, such as differential MORL altitude during a measurement period.
3. Secure Communications--The individual crew diaries must be transmitted to the ground in a secure manner. Assuming this is handled by transmitting the diary tapes at a higher-than-record-speed (playback-to-record ratio of 10:1), the ground-contact site must be capable of receiving a 30-kc analog signal and reproducing the intelligence at 3 kc.
4. Command--The primary experimental command requirements are the transmission of start-stop times and other pertinent experiment data.
5. Oceanographic Experiment Support Data--To check the validity of the oceanographic data obtained from the laboratory sensors, it is necessary to compare these data with actual direct measurements of the parameters involved. These parameters include ocean surface temperature, salinity, and wave height. Correlative data on atmospheric conditions, such as cloud cover, humidity, and so forth, are also required. Figures 8-1 and 8-2 indicate those portions of the orbit traces over which data are to be gathered.
6. Communications Experiment Support--The communication experiment requires an rf transmitter on the ground capable of transmitting sounding pulse signals in the frequency range 3 to 40 mc.

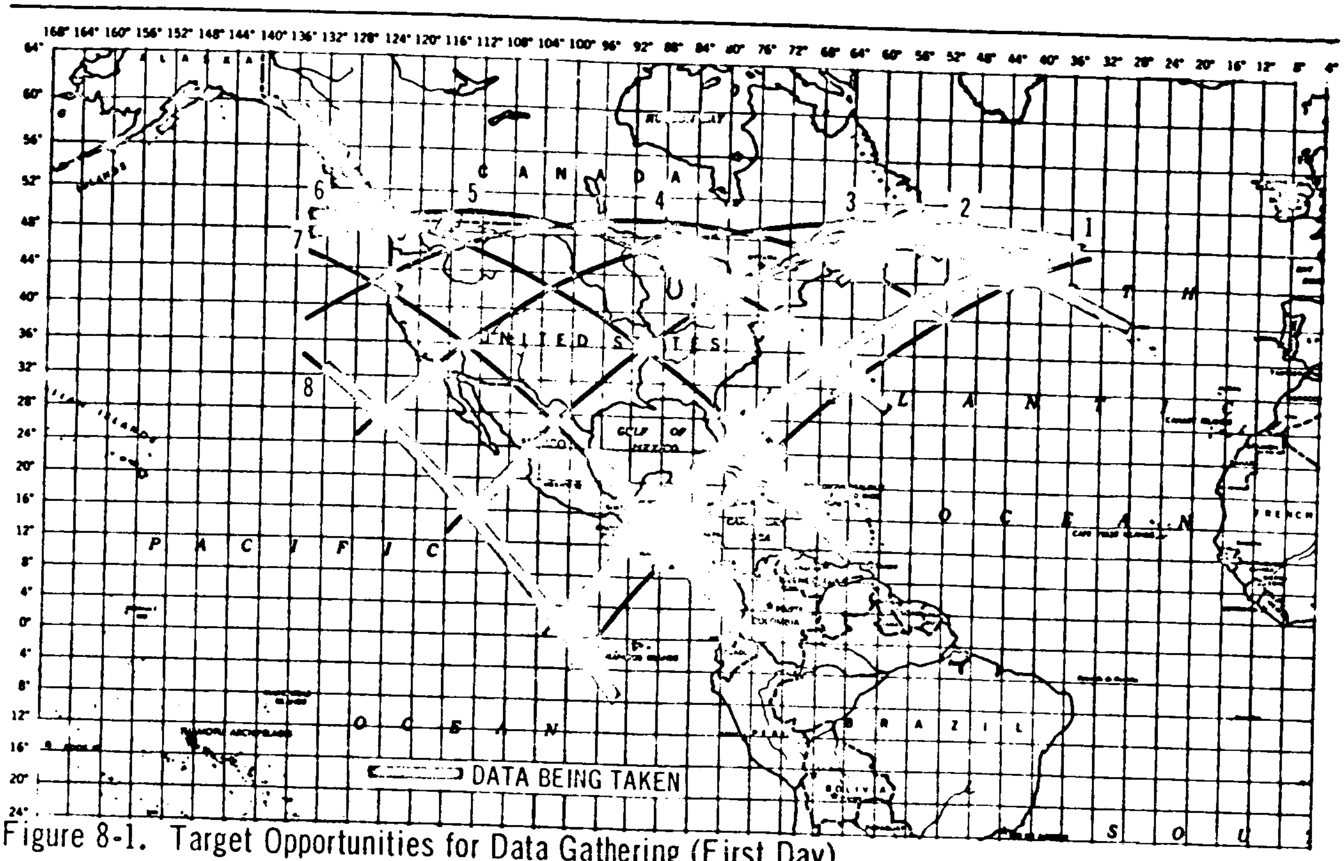


Figure 8-1. Target Opportunities for Data Gathering (First Day)

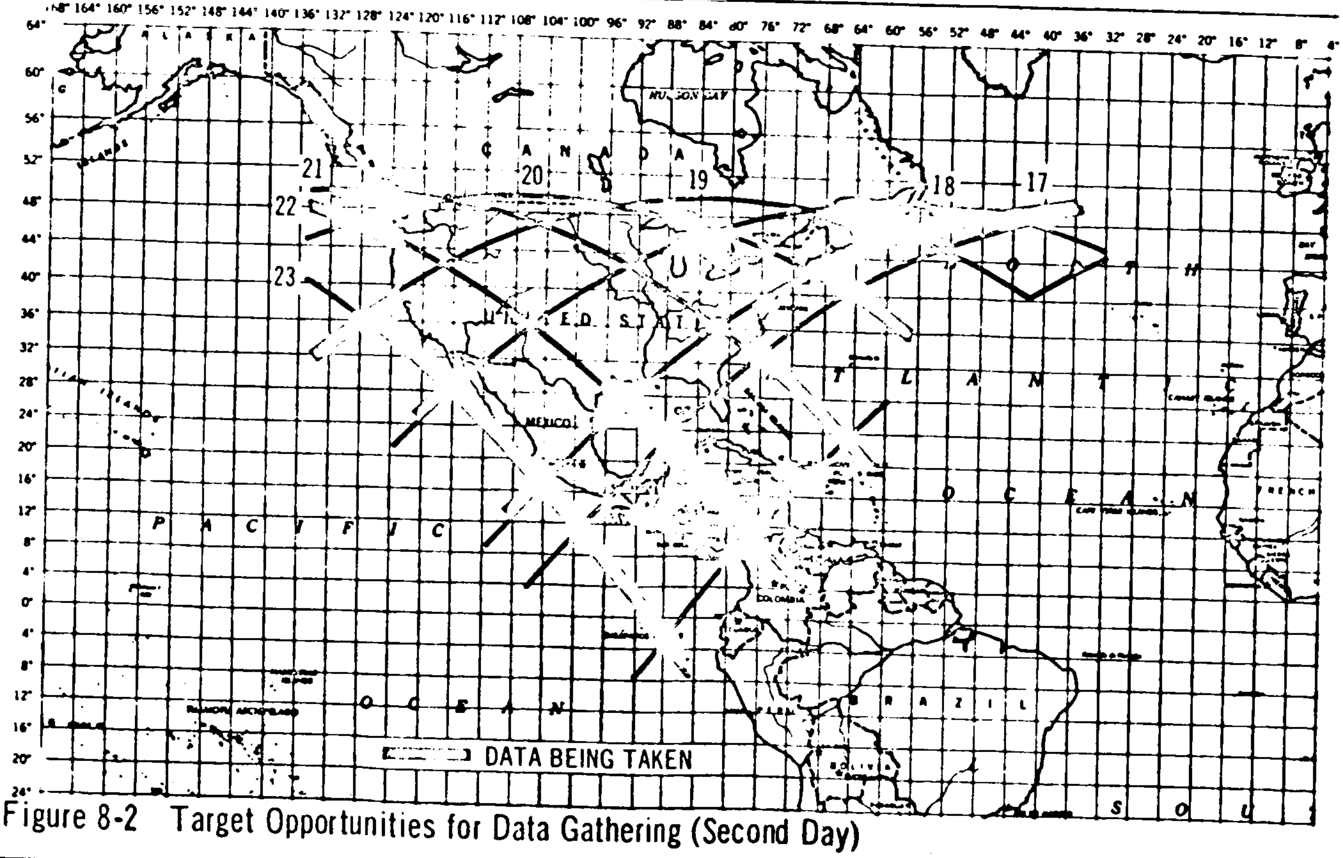


Figure 8-2 Target Opportunities for Data Gathering (Second Day)

8.2 DISCUSSION AND ANALYSES

The previous paragraphs have identified requirements on the ground-support systems which are imposed by the operational and experimental aspects of the 48-hour mission.

The operational requirements pose a coverage time problem to the ground network. The coverage provided by the baseline network (TEX and KEN) is tabulated for each orbit in Table 8-1 and is further displayed in Figures 8-3 and 8-4. The baseline network is marginal in providing the required 45 min./day telemetry dump time. Although approximately 50 min./day are available during this specific 48-hour period, studies have shown that the average is 43.25 min./day when a large sample is used. In addition, tracking capability is provided only during three, rather than four, successive orbits.

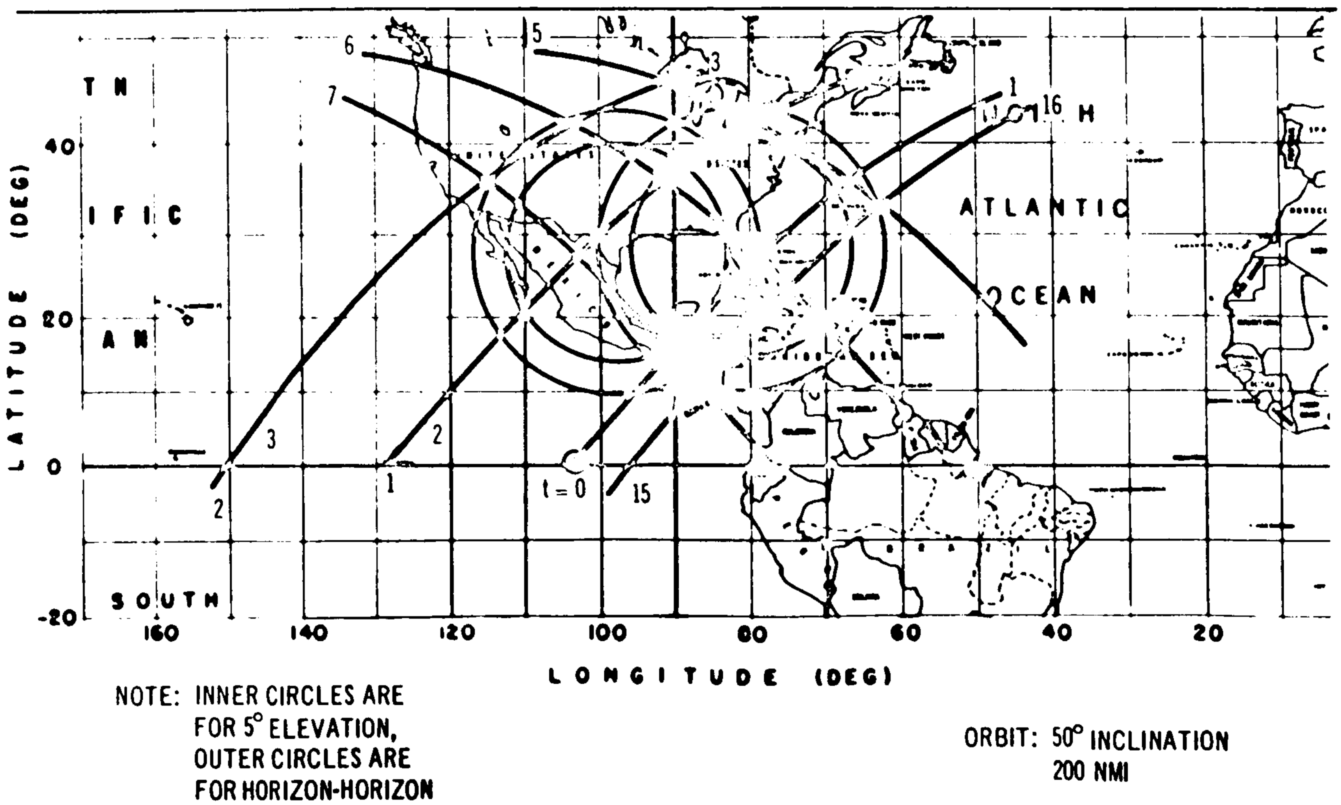


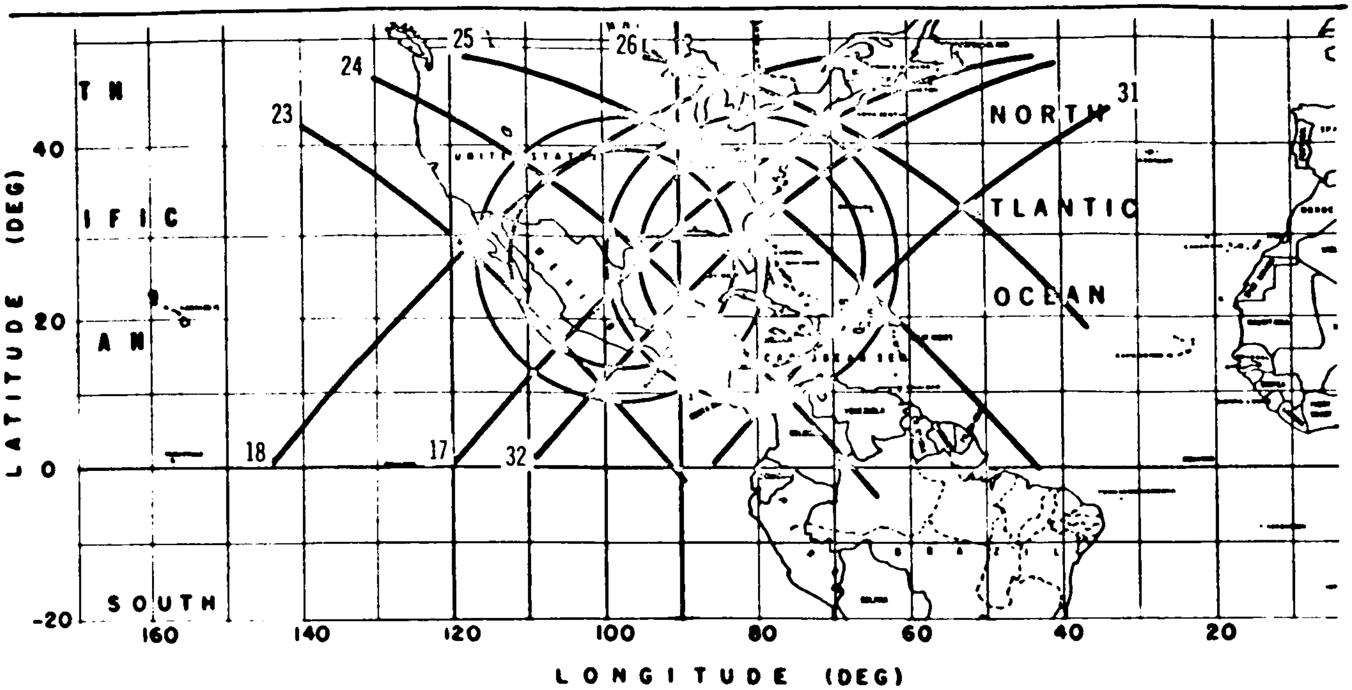
Figure 8-3. Coverage from Baseline Network (Corpus Christi and Cape Kennedy) – First Day

Table 8-1

COMMUNICATION COVERAGE SUMMARY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Orbit	Experiment Number	Experiment Start Time	Experiment Stop Time	Specified Experiment Duration	Baseline Track Site	Site Contact Start	Site Contact Stop	Site Contact Duration	Continuous Nonredundant Contact Time	Experiment Time Before Contact Established	Experiment Time After Contact Lost	Experiment Time Without Contact	Time Since Previous Contact to Experiment Start	Best Additional Site or Location
1	258,255	0	20	20	TEX KEN	4.50 5.75	9.50 13.75	5.0 8.0	9.25	4.5	6.25	10.75	--	--
2	258	97	117	20	TEX KEN	98.77 103.44	106.60 108.61	7.83 5.17	9.84	1.77	8.39	10.16	83.25	--
3	257,258	193	213	20	--	--	--	--	--	--	--	20	84.39	Guaymas
4	255	300	308	8	--	--	--	--	--	--	--	8	191.39	Minneapolis
5	257	386	404	18	TEX	397	400.58	3.58	3.58	11.0	3.42	13.42	277.39	--
6	257,255	484	502	18	TEX KEN	489.68 491.35	495.01 499.35	5.33 8.00	9.67	5.35	2.65	8.01	83.42	--
7	257,258 255	582	597	15	TEX KEN	584.62 589.28	592.62 592.70	8.00 3.42	8.08	2.62	4.30	6.92	82.65	--
8	257,255	680	692	12	--	--	--	--	--	--	--	12	87.3	Guaymas
16	--	--	--	--	KEN	1,384.44	1,391.52	7.08	7.08	--	--	--	--	--
17	252,257	1,476	1,495	19	TEX KEN	1,476.59 1,480.09	1,484.51 1,487.17	7.92 7.08	10.59	0.59	7.83	8.42	84.48	--
18	252	1,569	1,587	18	TEX	1,574.03	1,579.53	5.50	5.50	5.03	7.47	12.50	81.83	--
19	257,255 252	1,665 1,668	1,682 1,682	17 14	--	--	--	--	--	--	--	17 14	85.47 88.47	Hawaii
20	255	1,760	1,771	11	--	--	--	--	--	--	--	11	180.47	Minneapolis
21	252	1,860	1,878	18	KEN	1,869.50	1,876.75	7.25	7.25	9.5	1.25	10.75	280.47	--
22	252,257	1,957	1,973	16	TEX KEN	1,962.52 1,965.52	1,970.35 1,972.52	7.83 7.00	10.02	5.52	0.48	6.00	80.25	--
23	252,257	2,055	2,070	15	TEX	2,059.54	2,064.79	5.25	5.25	4.54	5.21	9.75	83.48	--
31	255	--	--	--	KEN	2,764.18	2,676.93	3.75	3.75	--	--	--	--	--
32'	--	--	--	--	TEX KEN	285 285.70	2,862.20 2,865.62	6.75 7.92	10.17	--	--	--	--	--

1. Orbit: No. 1 starts at lat. = 0, long. = 104; inclination = 50°, altitude 200 nmi.
2. Baseline sites: TEX = Corpus Christi, KEN = Cape Kennedy.
3. Minneapolis is not a valid site; however, a site in that vicinity would cover these cases.
4. The experiments of orbits 3 and 19 can be covered by Guaymas and Hawaii, respectively, without any shift in start time. However, the experiments of orbit 8 should start approximately 5 min. later than shown.
5. All times are given in minutes.
6. Contact times are for 5° elevation lock and unlock (track and DCS)
7. Voice contact (horizon - horizon) adds approximately 2 min. to each contact time.



NOTE: INNER CIRCLES ARE FOR 5° ELEVATION, OUTER CIRCLES ARE FOR HORIZON-HORIZON

ORBIT: 50° INCLINATION
200 NMI

Figure 8-4. Coverage from Baseline Network (Corpus Christi and Cape Kennedy) – Second Day

The solution to these limitations resides in expanding the network. The orbits during which coverage would be provided for selected additional ground sites is indicated in Figure 8-5. It appears that Hawaii would constitute an acceptable addition to the tracking network, permitting both requirements, telemetry dump time and tracking, to be met.

The tracking problems related to experiment support are of two distinct types, both of which, however, result from accuracy requirements. In the first case, the accurate generation of command data (primarily start-stop times or sensor pointing angles, if the sensor is not to be aligned along the local vertical) demands a knowledge of the MORL ephemeris to a commensurate accuracy. To supply the required ephemeris accuracy, the tracking and ephemeris determination functions must be performed only shortly before the commands are to be sent to the MORL. This will minimize the prediction or dead reckoning period during which ephemeris accuracy rapidly degrades. This implies

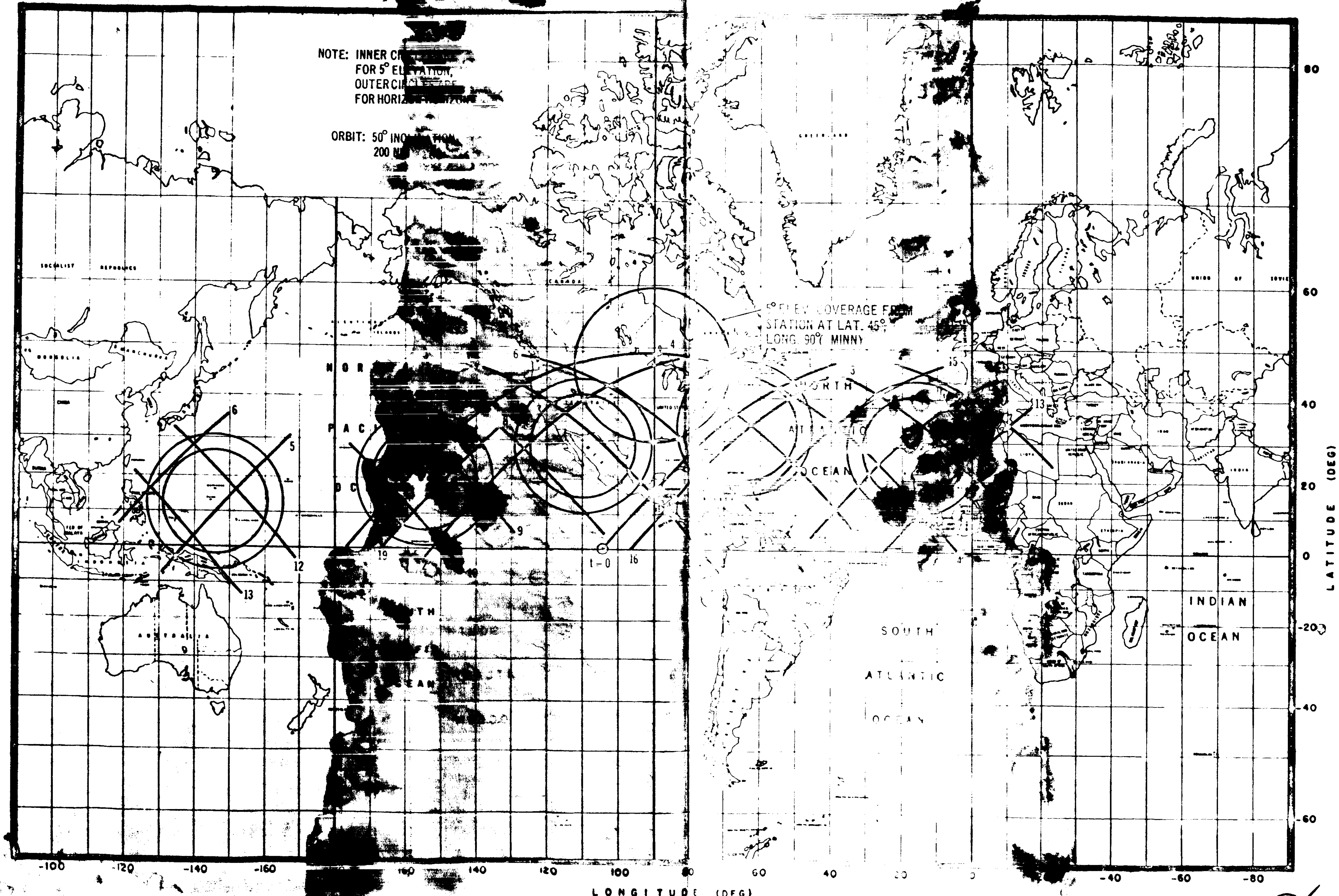


Figure 8-5. Coverage from Ad[illegible] Sites (L[illegible]uam, Hawaii, Guaymas, Bermuda, Canary Island)

more sites to minimize the occultation period, a restraint on when the affected experiments can be performed, or a nontracking-dependent navigation technique.

The second type of tracking problem results from the need to supply collation data for subsequent experiment analysis. As indicated previously, there is a need for the determination of the differential MORL altitude occurring during the measurement of sea slope and wave height. Actually, the experiment sensor measures relative distance between the MORL and the sea surface; therefore, MORL altitude above mean sea level is necessary for ultimate determination of the desired quantities. The accuracy to which the differential altitude must be known to preserve the desired experiment data accuracy (± 0.25 ft) demands that radar tracking be coincident with the experiment data-taking period; of course, basic radar accuracy may not be sufficient to support the requirement. This coincident tracking requirement implies that either the radars be located to support the experiments (this may necessitate the use of tracking ships) or the experiments be performed in conjunction with the baseline sites. It should be noted that although radar tracking must be real time, the subsequent computation of the differential altitude history must be performed only when the information is needed for experiment data collection.

Similarly, the time-line schedule of on-board operations, contained in the pocket attached to the rear cover of this book, indicates the incompatibility of target opportunities and available communications times.

The solution involves shaping a limited instrumented range to be consistent with contact capability. The present time-line schedule cannot, therefore, be implemented as indicated by the baseline network or any reasonable extension of same.

The support data for the oceanographic experiments would require the implementation of an instrumented ocean area approximately as outlined in Figure 8-6. The range would consist of a grid of permanently moored buoys

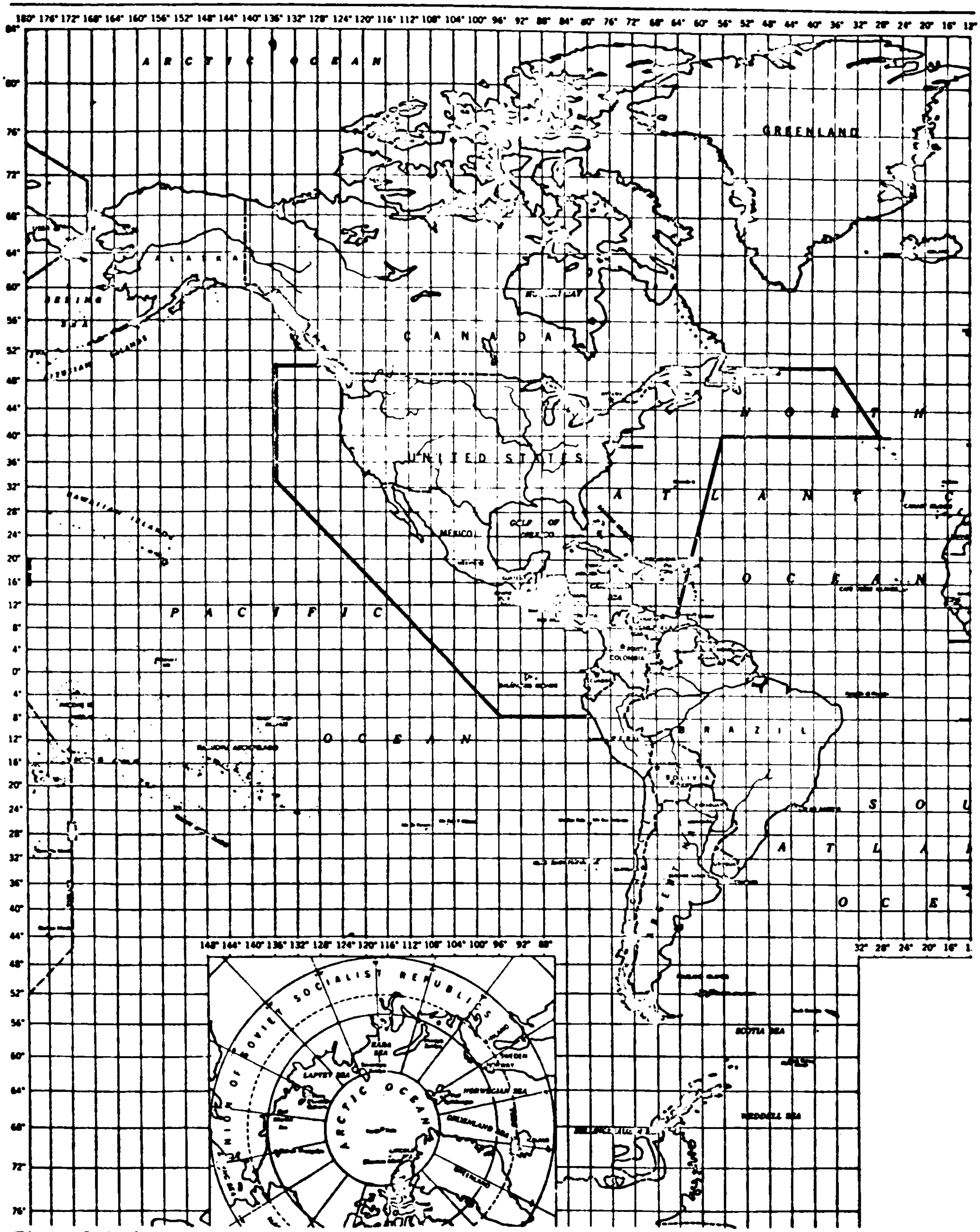


Figure 8-6. Instrumented Range

which would make sea-state measurements similar to those taken aboard the MORL. Examples of what these buoys look like are shown in Figure 8-7 and 8-8.

One problem associated with a buoy-equipped range is that the ground track of the spacecraft will, in the general case, pass between two buoys rather than directly over them. Since the spacecraft sensors are vertically oriented, it would be necessary to interpolate between buoy readings to get the actual sea conditions. The validity of this approach is obviously questionable, unless the spacing of the buoys is quite small.

Again, the indication is to reduce the range and the frequency of measurements, until direct or nearly direct flyover is possible.

There appears to be no major problem in providing an rf transmitter of the type required to support the communications experiment or in handling the secure voice requirements.

8.3 ADDITIONS AND MODIFICATIONS REQUIRED

Operational and experimental requirements both indicate the need for network expansion. The addition of Hawaii (HAW) to the network composed of TEX and KEN would satisfy the operational requirements.

Experimental requirements cannot be satisfied as stated. A reasonable modification would be to reduce the scope of the oceanographic experiments to less frequent measurements over a reasonably limited range.

8.4 TIME-LINE ANALYSIS

A time-line schedule of mission operation and support activities is shown in Figure 8-9. Three groups of activities are shown: (1) those associated with the IMCC, (2) the remote network activities, and (3) the experiment support network activities. The schedule of these activities is consistent with the time-line schedule of laboratory activities.

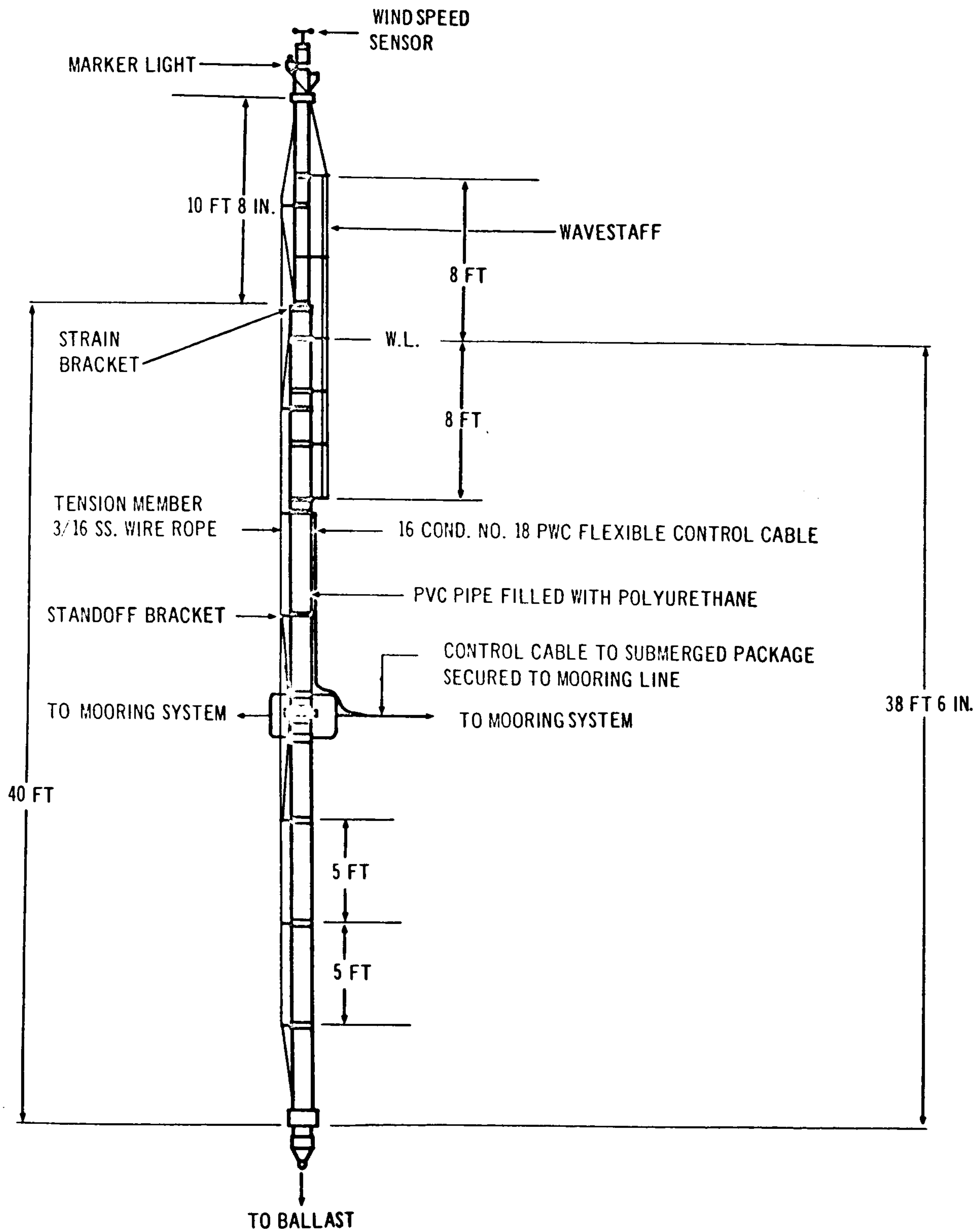


Figure 8-7 SPAR Buoy Assembly

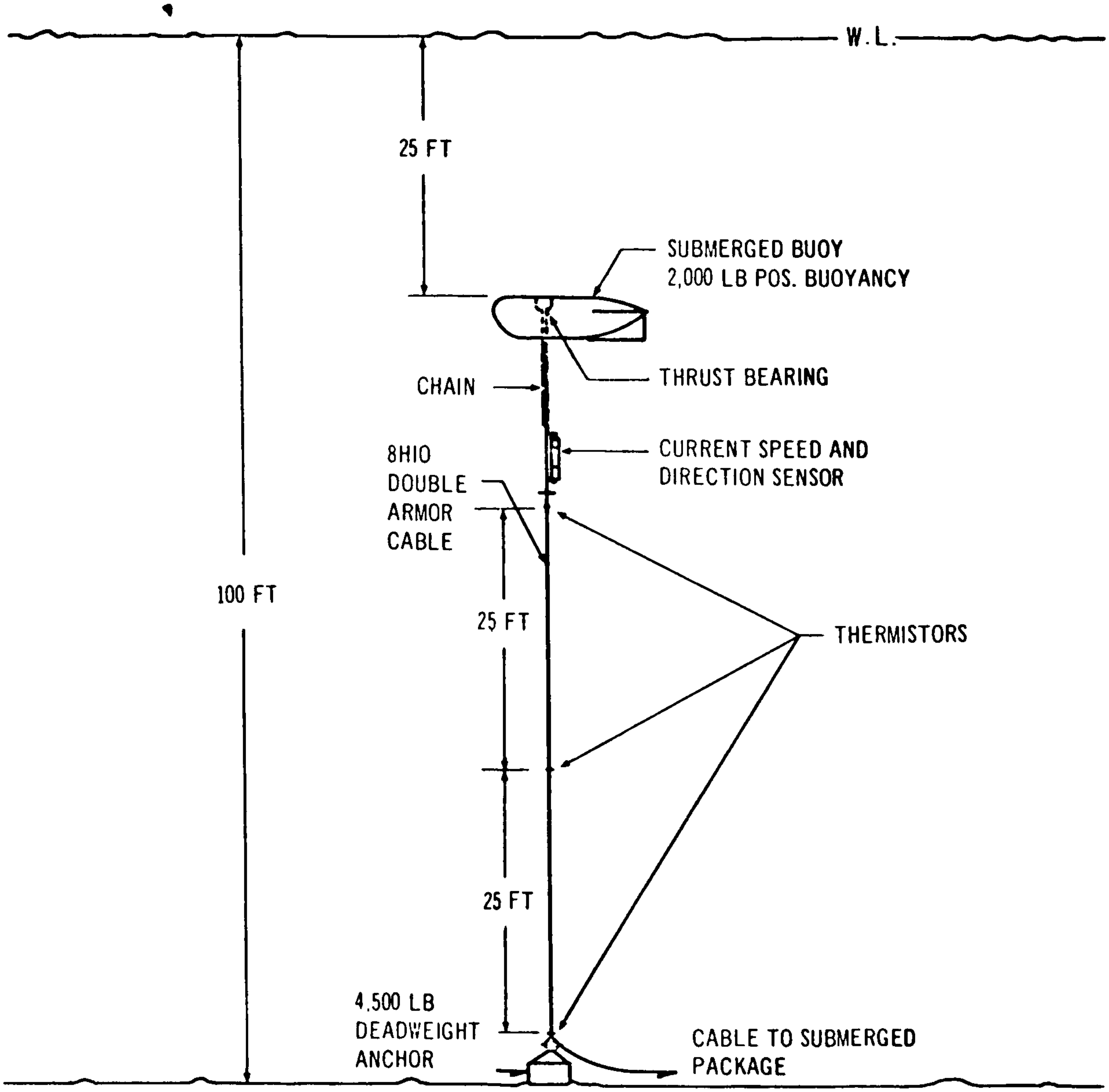


Figure 8-8. Submerged Buoy Assembly

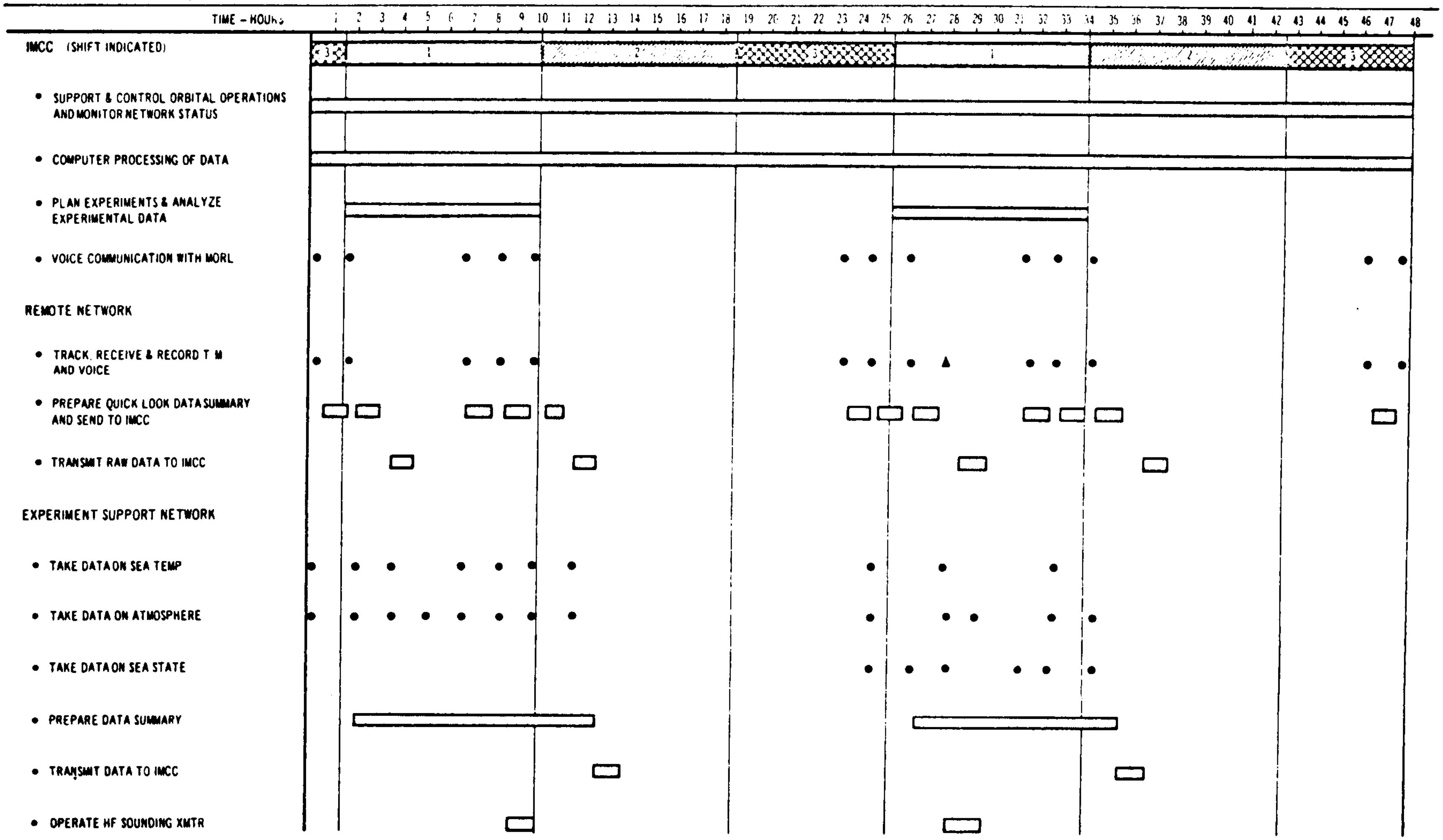


Figure 8-9 Mission Operation and Support – Time Line Schedule

As indicated, the IMCC is operated on a 24-hour per day basis to perform the routine functions required to monitor network status, receive and process data, and, in general, support and control orbital operations. The major activities, particularly experiment planning and analysis, are, however, concentrated within the day-shift hours.

Within the 48-hour schedule shown, there are 13 periods during which communication with MORL is possible (utilizing only the baseline network). Each of the opportunities is utilized for voice contact, reception and recording of telemetry data, and for tracking. It is noted that there is a requirement for tracking during the 28th hour to support the radar experiment, but this requirement cannot be met by the baseline network.

Shortly after each communication contact with the MORL, the remote sites formulate a quick-look data summary and transmit it to IMCC. Raw experimental data are collected for three successive contact times and then transmitted to IMCC for detailed editing, reduction, and analysis.

The experiment support network is primarily engaged in obtaining sea and atmospheric data within the target areas of the oceanographic experiments to be used as a reference in evaluating experiment data. Data are taken at several scheduled intervals during the first half of each 24-hour period. As these data are gathered, a summary message is prepared and, shortly after the conclusion of each series of measurements, the summary message is transmitted to IMCC to be available for the next day shift.

The rf transmitter required for the communication experiment is operated for approximately 1-orbit period during each 24-hour period, as indicated in the time-line schedule.

8.5 RECOMMENDED FOLLOW-ON STUDIES

The recommended studies fall into two categories, that is, those within the intent of Task IV (Phase IIb) and those beyond the scope of Phase IIb.

For Task IV, the primary studies reside in the area of network optimization. The recommendation of adding Hawaii to the baseline network should be analyzed relative to such parameters as average network coverage, contact sequence, and so forth.

The primary additional studies revolve around the need for better definition of navigation techniques and accuracies. The baseline navigation technique should be reinvestigated to indicate procedural requirements and accuracy as a function of time. The need for autonomous navigation on board the MORL to support experiments, such as the oceanographic, is clearly indicated and should be investigated.

Section 9
PERTURBATION ANALYSES

The first portion of the 48-hour study concerned itself with the formulation and analysis of a 2-day period of MORL operations in which all activities proceed without major incident. The second part of the study examined the effect of disturbances, caused by some planned and unforeseen events, to these smoothly accomplished activities.

The purpose of this investigation was to determine the effect of these disturbances on the original schedule; the impact, if any, on the experiment program; the extent of crew involvement; and if the inherent capability of the baseline MORL was adequate to support the necessary corrective actions.

9.1 SELECTION OF EVENTS TO BE EXAMINED

For each major laboratory subsystem, a single event which would require either immediate or timely attention was selected for detailed analysis. These events included the following:

1. EC/LS--CO_2 level increase above allowable.
2. Communications and Telemetry--C-Band transponder failure.
3. SCS--Control moment gyro bearing failure.
4. Electrical Power--Battery failure.
5. Propulsion/RCS--Engine replacement.
6. Orbit keeping operation.

The first four events consider unforeseen failures to modules/components in the subsystems. These events represent tasks which cannot be scheduled in any manner, although some amount of crew time, based on a statistical approach, may be reserved for such an occasion. These events, because of their unexpected arrival, tax the ability of the flight crew to respond with the speed required to avoid major damage to themselves and to the MORL facility.

The engine replacement operation can be either a scheduled or unscheduled event. The accumulated burntime of each engine is periodically monitored by both the flight crew and the ground station. When an engine approaches the end of its useful life, the necessary precautions and steps for replacement are taken. The analysis performed on this event is also valid for the case when an engine fails as a result of some cause other than longivity.

An orbit-keeping operation was examined here because of the frequency of this event. This operation occurs approximately once every 7 days. Unlike the other events this task is well scheduled in advance and becomes quite routine, particularly in the 2nd year of operation chosen for this 48-hour study.

9.2 DISCUSSION OF ON-BOARD ACTIVITIES

The device chosen to present each event is the activity flow diagram. These charts illustrate the logical flow of operations by identifying each task to be performed and each decision to be made (see Figure 9-1). Time estimates are made for each task to determine elapsed time per event and the extent of flight crew involvement. The degree of involvement by each crewman is also identified by separating those tasks for which each is responsible. Tasks shared by more than one crew member are so indicated.

For each event examined, the first indication of a failure, verification of failure, isolation of the failed module/component, repair of same, and verification of successful repair are indicated on the diagrams by heavy lines.

Numbers are used to identify each task and decision. The code letters C, D, O, A, A_A, and AA refer to the specific crew member, Flight Commander, Deputy Flight Commander, Operations Engineer, any other crew member, any other crew member*, and any other two crew members, respectively. The numbers indicate events. When two crew members are involved in the same task, the one initiating the task has his code letter used first; for example, A7/C1 of Figure 9-1 indicates the crewman assigned to monitor station status has notified the Flight Commander.

*Any other member of the crew available for this assignment.

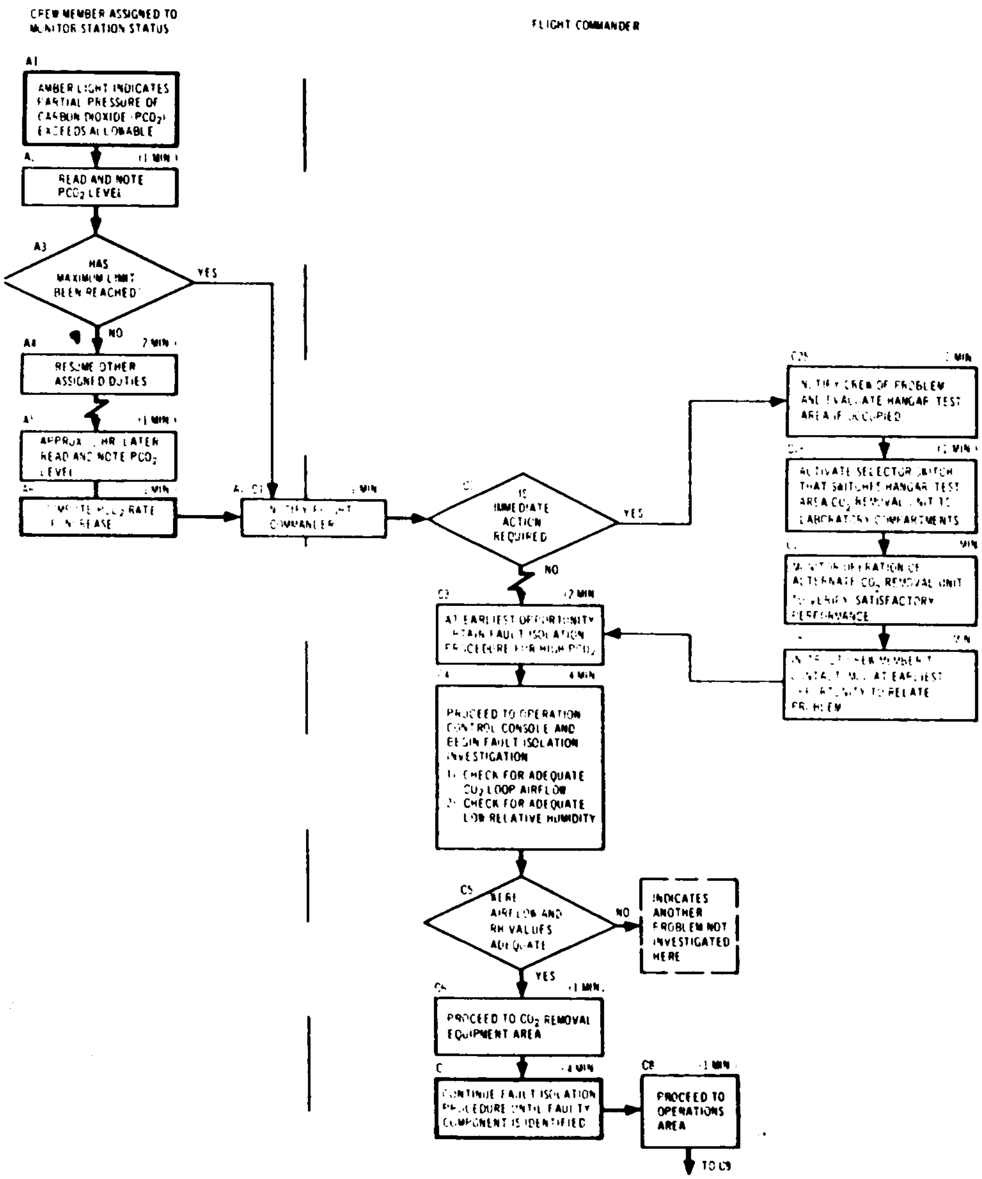


Figure 9-1. Activity Flow Diagram for CO_2 Level Increase Above Allowable

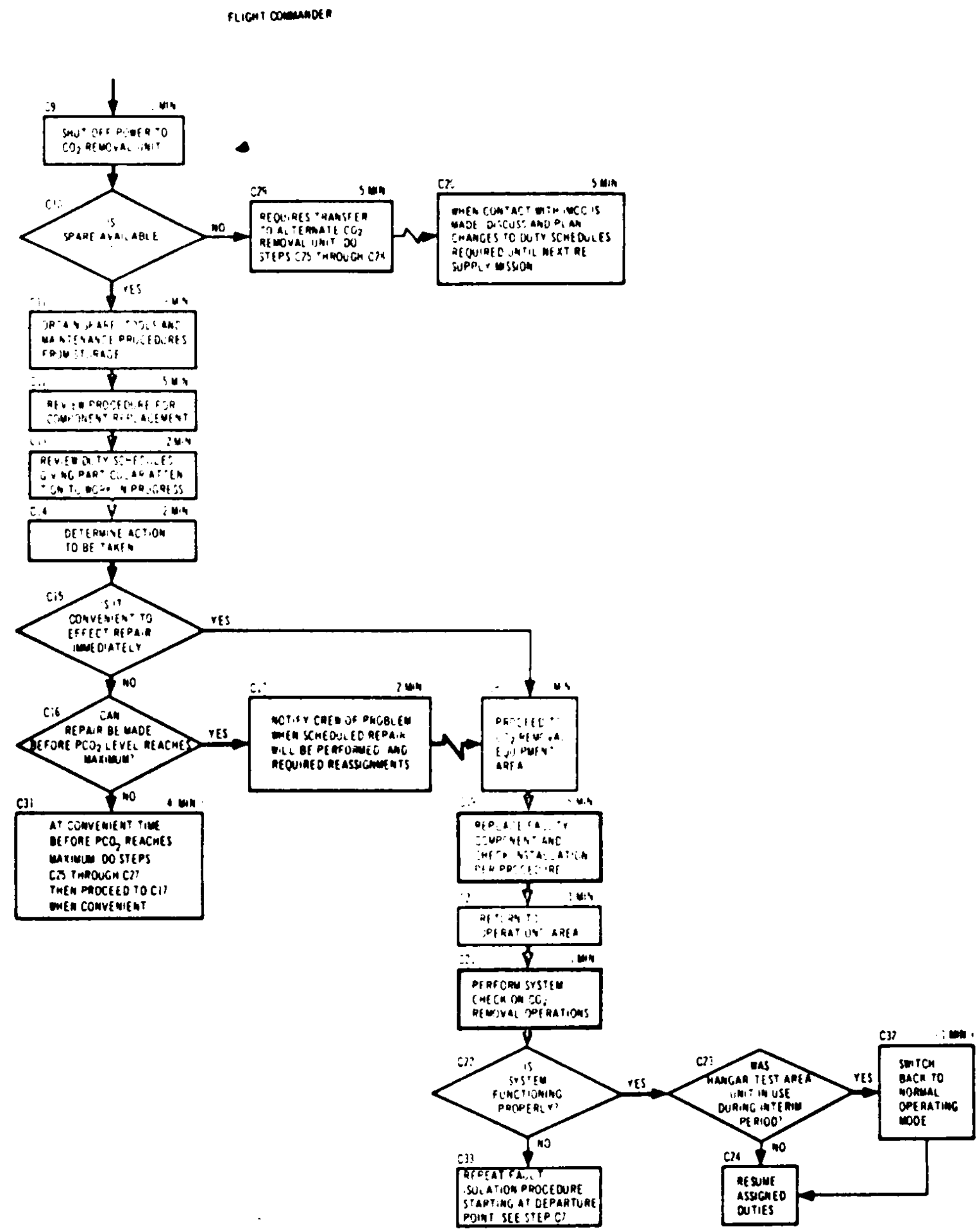


Figure 9-1. Activity Flow Diagram for CO_2 Level Increase Above Allowable (Continued)

9.2.1 CO_2 Level Increase Above Allowable

This event was chosen for EC/LS subsystem analysis because it demonstrates the flexibility inherent in the baseline MORL design. The activity flow diagram for this event is presented in Figure 9-1.

After the initial indication that the partial pressure of CO_2 (PCO_2) in the main laboratory atmosphere has exceeded allowable levels, the rate of increase is calculated and the Flight Commander is informed of the criticality of the situation (events A1 through A6). At this point the commander must determine the approximate time remaining before the PCO_2 reaches the danger point.

If the level of PCO_2 is too close to the danger point, the commander can choose to switch the hangar/test area CO_2 removal system to operate on the laboratory atmosphere (C25 through C28). Since the CO_2 removal system of the hangar/test area is identical to the laboratory system, normal laboratory operations can proceed almost indefinitely. To effect this switchover, it will be necessary to evacuate any of the crew members who are in the hangar/test area and to modify activities there accordingly. Alternatively, the commander can let activities continue in the hangar/test area until a convenient break in point is reached. Then he can switch the hangar CO_2 removal system (providing, of course, that he can let the situation in the main laboratory continue during this period).

Most of the time, the out-of-tolerance condition will be perceived shortly after it occurs and, assuming a normal rate of increase (0.5 mm/hour), up to about 30 hours may be available before the level reaches the maximum permissible. In this case the commander can wait for a convenient period to determine the exact nature of the failure (C3 through C15).

Even after he has determined the repair action required, the commander has alternate choices (C15 and C16). He can repair immediately if convenient (C18 through C24). Or, alternatively, he can wait until later provided PCO_2 concentration permits.

The activity flow diagram of Figure 9-1 shows the Flight Commander not only making the decisions but also effecting the repairs. This is solely the result of his skill, assumed for the baseline crew composition, being that of the EC/LS specialist. Normally, he would function only in the decision making capacity.

9.2.2 C-Band Transponder Failure

The activity flow diagram for this event is present in Figure 9-2. In this case, the flight crew are unaware that a problem exists. During a routine communications contact with IMCC, the MORL is notified that poor tracking returns, followed by a check of the ground radar equipment, indicate a laboratory failure, probably the C-Band transponder. The initial assessment to be made (Task A4), concerns itself with exactly where in the tracking sequence the MORL is. The following considerations apply:

1. If the problem occurs on the first of the three successive tracking contacts, the time criticality of the problem has to do with repair prior to the third contact. Available repair time is on the order of 180 min. (two orbits); therefore, repair prior to the third contact is possible if initiated immediately.
2. If the problem occurs on the second or third contact, the time factor is less critical because the next contact opportunity after repair is accomplished is at least 5 hours away.

The evaluation in Task C2 is similar but considers the following:

1. Availability of the Operations Engineer, who has the necessary qualifications and skills, for approximately a 140-min. period.
2. Impact of changing the Operations Engineer's schedule on the total crew and experiment program schedules.
3. Impact of the loss of tracking data on subsequent navigation up-date accuracy and, therefore, on quality of navigation support to operations and experiments.

In Task 04 the specific cause of the problem is identified. It is expected that maintenance can be performed without the removal of the total unit from its rack because removal would require the disconnect of the coax-cables and so forth. Also, the unit is located in the Operations and Subsystems Control Console, which is accessible from the rear and in close proximity to the Maintenance and Experimental Control Console.

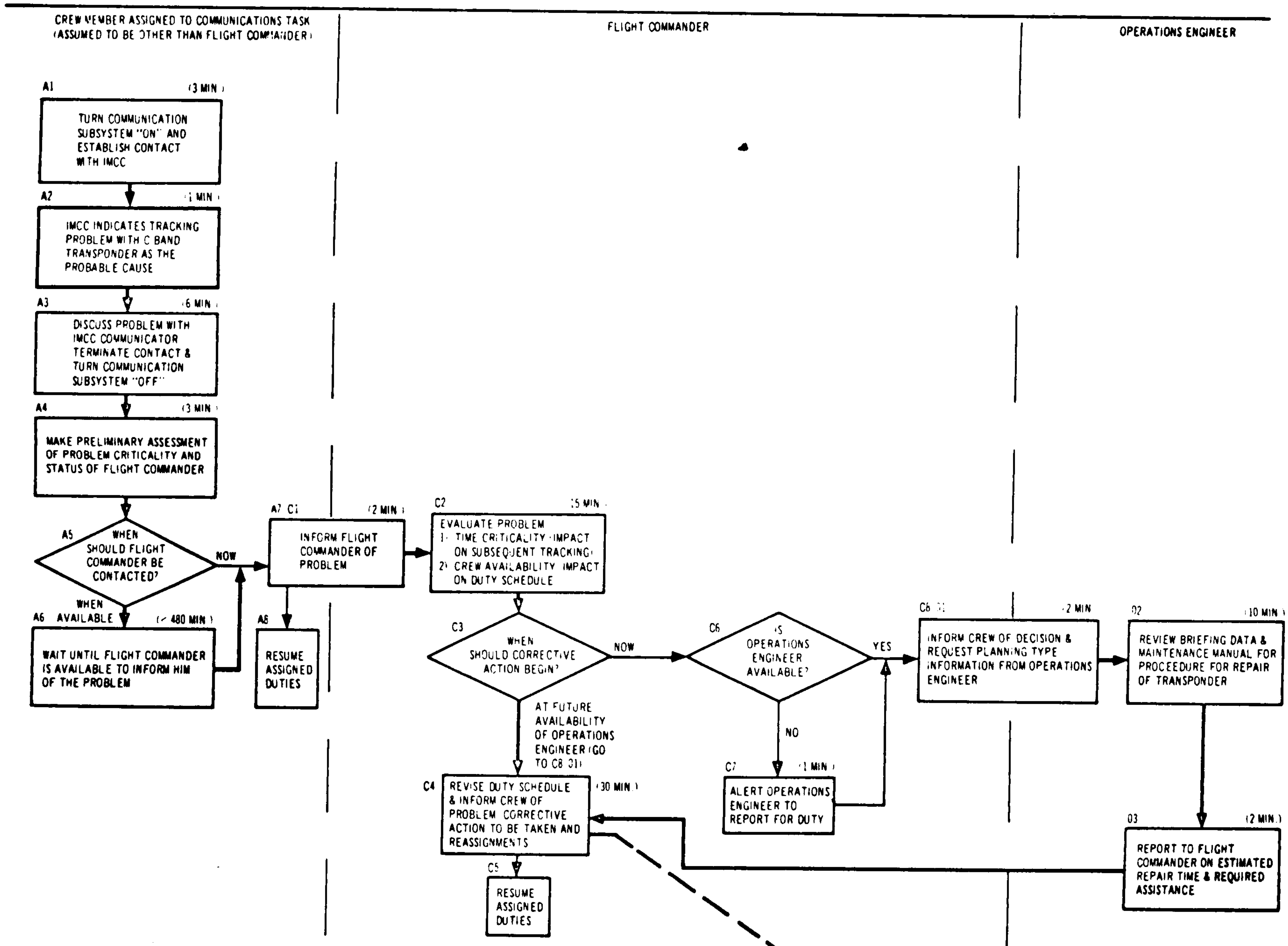


Figure 9-2. Activity Flow Diagram for C-Band Transponder Failure

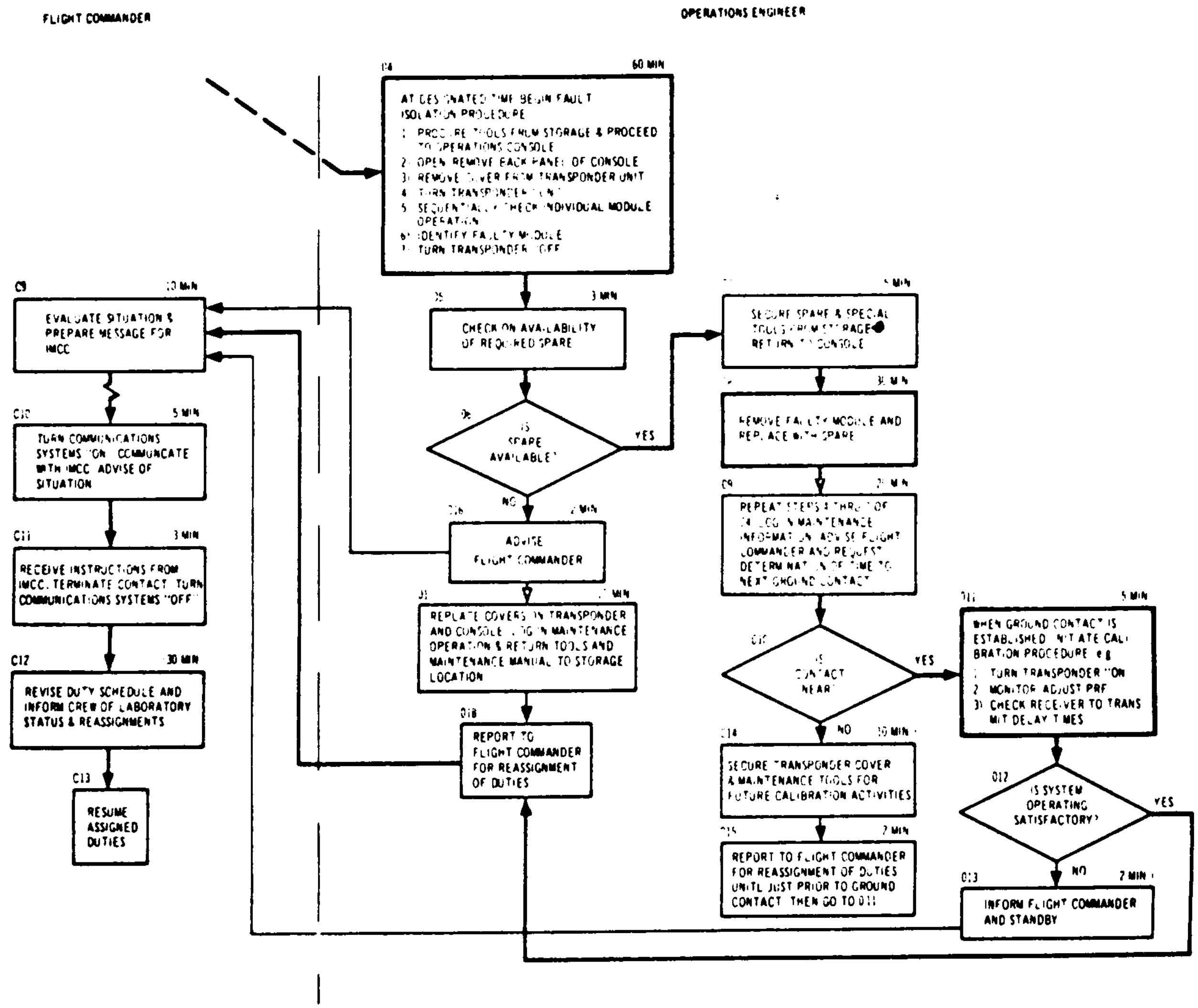


Figure 9-2. Activity Flow Diagram for C-Band Transponder Failure (Continued)

In Task 011 the successful repair of the transponder is verified. Repair checkout, calibration, and so forth must be performed while the system is functioning in the normal mode, that is, receiving pulses from the ground and transmitting respond pulses to the ground. Calibration includes the following:

1. Check of received and shaped pulse waveforms.
2. Check of receive-to-transmit delay time (critical for proper range measurement at ground).
3. Check of transmitter PRF and so forth.

The Flight Commander is required to perform the evaluation indicated in Task C9 when any one of the three following conditions occurs:

1. If there is no spare on board, subsequent tracking will not be possible (except skin tracking with great reduction in accuracy) until after the next resupply mission. Therefore, experiment schedules must be adjusted relative to those experiments requiring high navigation accuracy. Also, the degradation of future navigation accuracy will influence such factors as the initialization of the re-entry vehicle navigation system and so forth. The ground site must be advised of the situation and subsequent action must be discussed (change of duty schedules and resupply).
2. If the transponder does not check out properly during passage over ground site, the situation must be discussed with the ground as in Item 1 above.
3. If transponder checkout is satisfactory, the ground will be so informed.

9.2.3 Control Moment Gyro Bearing Failure

Figure 9-3 illustrates the on-board activities associated with the control moment gyro (CMG) bearing failure. The double gimbal control moment gyros (DGCMG) are equipped with a variety of sensors to detect abnormal conditions within each unit.

Outputs from these sensors are compared to acceptable threshold values and an out-of-spec indication from any sensor initiates a Warning or Caution indication.

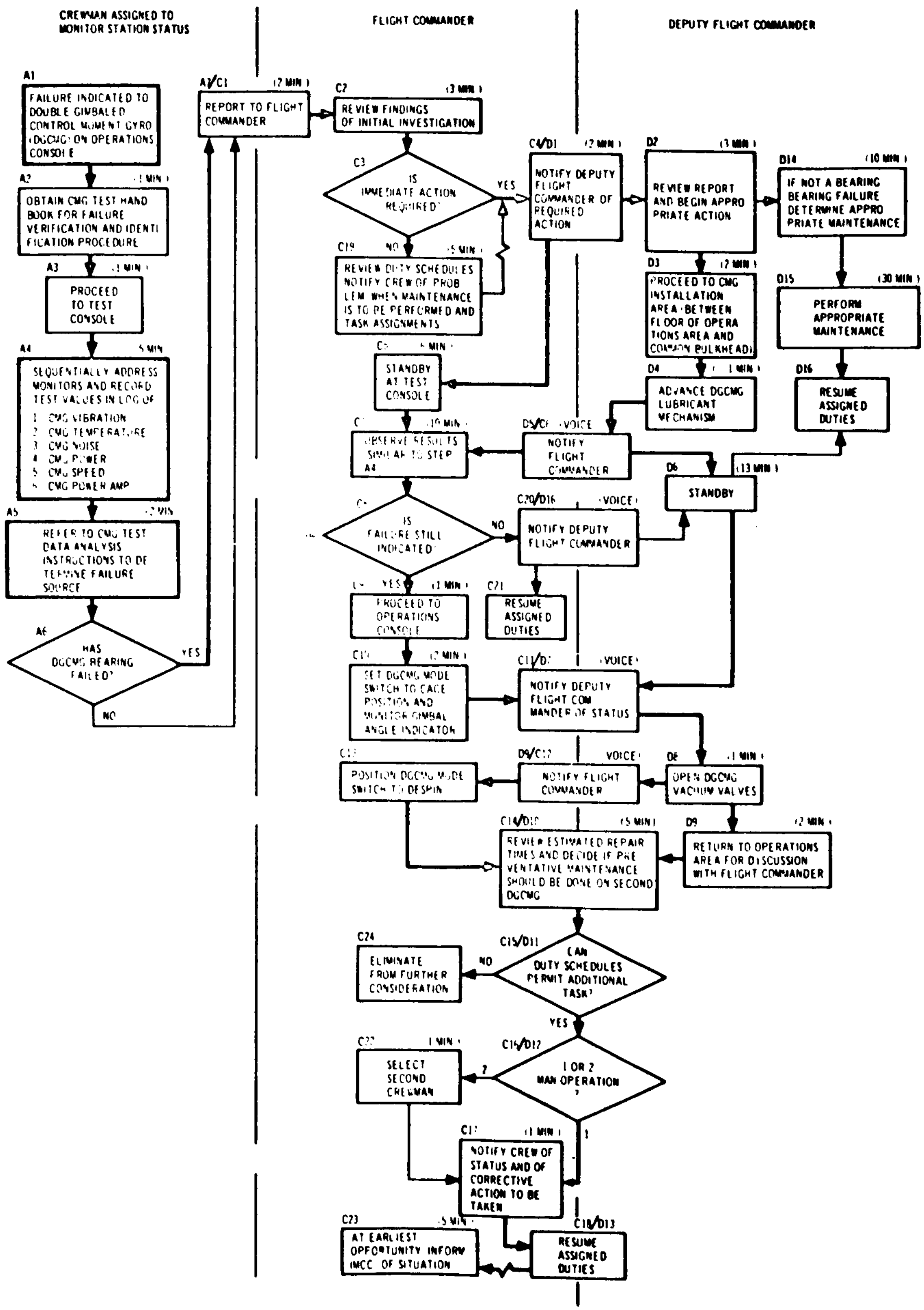


Figure 9-3. Activity Flow Diagram for Control Moment Gyro Bearing Failure

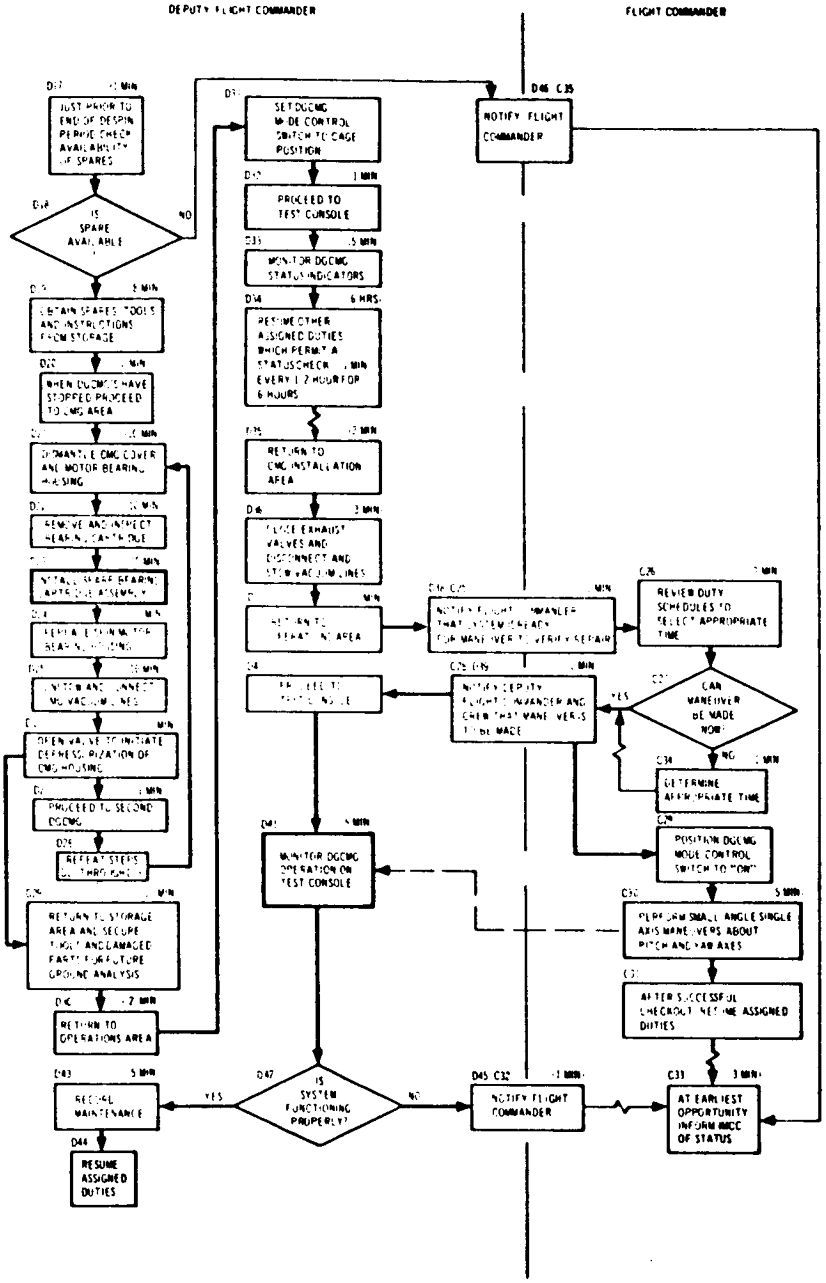


Figure 9-3. Activity Flow Diagram for Control Moment Gyro Bearing Failure (Continued)

A failure indication, Event A1, is first given on the CMG control panel by the illumination of a Caution/Warning light. In this case, it is assumed that the DMG-1 failure light has been illuminated. As soon as the operator becomes aware of the failure, he is required to verify the failure and identify its sources. For this purpose, he goes through the failure identification and isolation procedure. When it has been established that the failure indication is caused by a DGCMG bearing failure, and not a failure in the warning mechanism itself, he notifies the Flight Commander who has the responsibility to plot the required course of action.

A gyro failure indication requires immediate attention because a failure, if allowed to persist, may result in a wheel fracture constituting a safety hazard to the crew. The gyro wheels are designed for safe operation under normal conditions and there is no provision to contain the unit should a fracture occur (for example, a piece of the wheel may puncture the laboratory structure). For this reason, abnormal conditions, such as unusual vibration or temperature, should not be allowed to persist.

Several types of failure could occur and some of these may induce secondary failures. The most probable failure is in the lubrication mechanism. Additional lubricant is periodically required to replace that lost by vaporization or sublimation in the evacuated interior of the wheel housing. Either an insufficient or an excessive amount of lubricant in the bearing area could cause an abnormal indication. Insufficient lubricant will increase bearing friction, and cause the bearing temperature and spin motor power requirement to increase. Excessive lubricant will increase viscous drag and cause similar symptoms; however, temperature may not increase as much because the lubricant will act as a heat sink. For reasons such as these, it is necessary to examine all the sensor outputs before a failure diagnosis can be made.

In the example chosen, it is assumed that the bearings are not being lubricated properly, so the first action following failure identification is to attempt to restore lubricant circulation. The mechanism which injects lubricant fluid from the reservoir to the wick is manually activated, Task D4, by the Deputy Flight Commander who has the specific qualifications and skills for SCS maintenance. Time is then allowed for the lubricant to be circulated through the bearing. During this operation the Flight Commander monitors the control panel.

It is necessary for the Flight Commander at the control panel to monitor the results on the bearing for approximately 10 min. If a failure is still indicated at the end of this time, it is necessary to begin shutdown procedures. For this purpose, both control switches are placed in caged positions (Task C10). This automatically switches the SCS to reaction jet control about the pitch and yaw axis.

Since the addition of lubricant has not corrected the problem, the bearing assembly must be replaced. This includes the wick and all gaskets, sleeves, seals, and devices associated with the affected bearing and lubrication system.

Since DGCMG-2 will be despun and not used while DGCMG-1 is shut down, the Flight Commander may elect to perform preventative maintenance on DGCMG-2 at the same time that DGCMG-1 is down for repairs. This decision depends on how long since the last bearing replacement, whether or not he has two crewmen qualified to perform the maintenance procedure, or if he can afford the additional time required for one crewman to replace both bearings. This decision must be made at the time the failure occurs.

For this perturbation study, it is assumed that the Flight Commander will elect to replace the bearing cartridges in both DGCMG's. With the mode control switch placed in the caged position, the double gimbal units are locked in position and provide no control torque. The two single gimbal control moment gyros (SGCMGS) controlling the X-axis should still be operational. The X-axis gimbal indicator located at the control console, is monitored for 1.5 min. to determine if the X-axis momentum storage system is functioning properly. Continued use of the SGCMGS allows the centrifuge to be used during the period of despin and spin-up without excessive loss of reaction control propellant.

To facilitate the despin, the Deputy Flight Commander at the DGCMG location opens the DGCMG vacuum valves to admit ambient air to the gyro housing. The Flight Commander at the control console location then switches the DGCMG mode switch to DESPIN. This causes the CMG wheels to begin to slow down. Both crewmen may now return to their normal duties for the 3-hour period required to despin the gyro wheel.

The CMG control panel should be checked approximately once every 1/2 hour to determine that despinning is proceeding normally. When the CMG has stopped spinning, the Deputy Flight Commander unstows the CMG tools and spare bearings. He then proceeds to the CMG installation area. The covers and bearing housings of both CMG's are then dismantled. The bearing cartridges are removed and inspected. The bearing of the DGCMG that failed should show signs of wear or damage. If it does not, a close check of the CMG support housing and wheel must be made before spin-up. In any case, replacement bearing cartridges should be installed on both double gimbal CMG's. The spin motor bearing housings and CMG covers are then replaced on both double gimbal CMG's. The vacuum lines are then unstowed and connected to the CMG's to allow an evacuation of the gyro housings by venting to the outside of the vehicle. The procedure calls for simultaneous CMG housing depressurization and spin-up.

After the CMG tools and damaged parts have been stowed in the storage area, the Deputy Flight Commander returns to the operations area. The mode control switches for the double gimbal CMG's are switched to CAGE. This causes the gyros to begin to spin up. The CMG status indicators are then monitored for 5 min. continuously and for 30 sec every 1/2 hour thereafter for a total of 6 hours (Task D34). During this time, the Deputy Flight Commander is free to perform other duties which do not interfere with the 1/2-hour checks.

At the end of 6 hours, the Deputy Flight Commander proceeds to the CMG installation area while the Flight Commander remains at the CMG control panel. The crewman in the installation area closes the exhaust valve, disconnects the vacuum lines, and returns to the operations area. The double gimbal CMG mode control switch is then turned to ON (Task C29).

This causes stabilization about the pitch and yaw axis to be returned to momentum storage control. To test for normal operation, small single-axis maneuvers are performed about the pitch and yaw axes while the double gimbal CMG operation is monitored on the CMG control panel. This should be done for a period of approximately 5 min. Assuming operation is normal, the entire maintenance event is recorded in the maintenance log and the crew returns to routine operational procedures.

9.2.4 Battery Failure

An activity flow diagram for a battery failure is presented in Figure 9-4. As indicated, a warning light indicates that a battery has failed and the specific battery involved is automatically identified. The system is designed so that a failure of this type will result in the defective battery being automatically switched out of the system. If the automatic equipment does not work, switching may be accomplished manually (Task A6).

It is important that a failed battery be removed from the system to avoid affecting other components and to avoid further battery damage. When a battery has failed, the reason for failure could cause gas generation within the cell; continued operation of battery could result in a build-up in this gas pressure and possible explosion of the cell.

Task C3, indicates that the Flight Commander must immediately review current and planned electrical loads to determine if a reduction in system loads is required. This is especially necessary when full or nearly full power loads exist. Continued operation at full power could place a severe drain on the other batteries. The reduction of loads, if required, would only apply to the dark portion of the orbit as full power, supplied from the solar panels, will still be available when the laboratory is in lighted areas.

IMCC will be notified that a battery has failed and that the crew activities have been rescheduled. The control center may already be aware of the failure, or of an approaching failure, because of the automatic monitoring system. Also, the control center may want to change some of the load priorities, and the center would probably check out the availability of spares and make preparations for a resupply of the battery, if necessary.

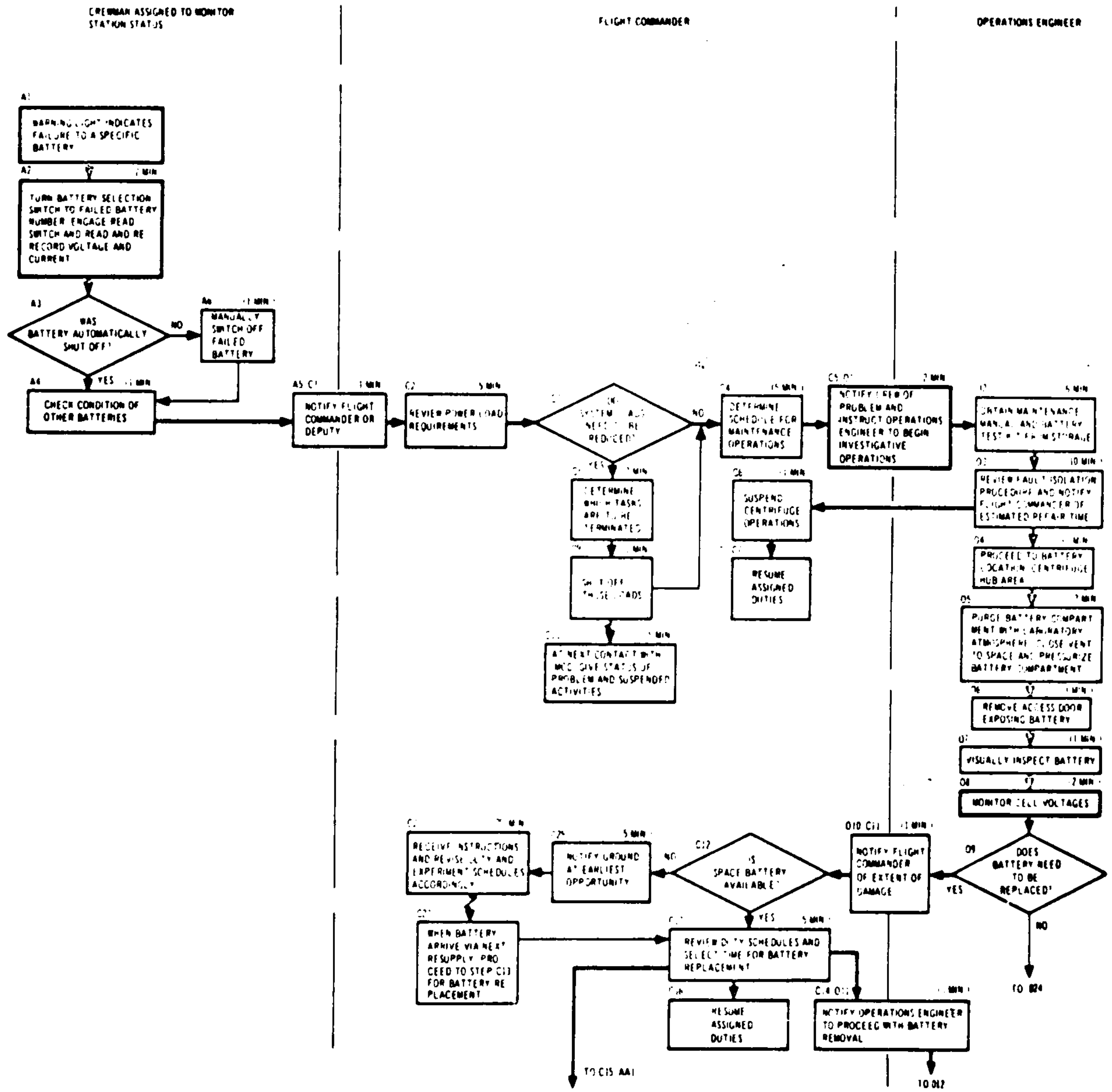


Figure 9-4. Activity Flow Diagram for Battery Failure

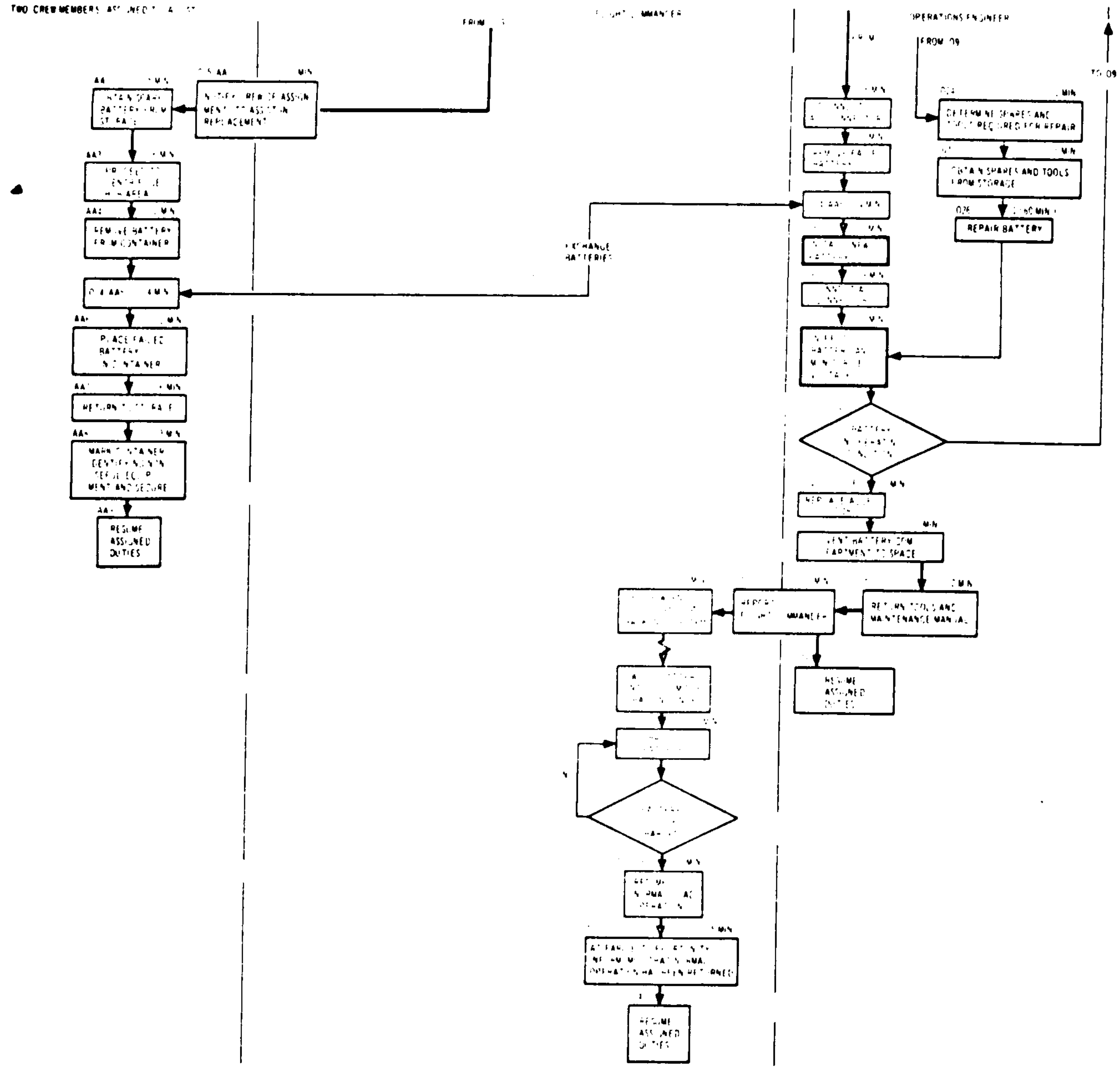


Figure 9-4. Activity Flow Diagram for Battery Failure (Continued)

The centrifuge operations are suspended (Task C6) because the batteries are located in the centrifuge hub area. If the centrifuge is in use, the Flight Commander will make the decision to complete or terminate that activity.

The Operations Engineer is assigned to the investigation of the failed battery because of his qualifications and skills. He will obtain the maintenance manual and the test kit for the battery and proceed to the centrifuge hub area. (Task 02 through 04). He will prepare for the inspection of the battery by first venting the laboratory atmosphere through the battery compartment to assure the removal of the KOH electrolyte that could be present and contaminate the lab environment (Task 05). The valve between the battery compartment and the atmosphere is then closed and the battery compartment is pressurized. The battery compartment access cover can now be removed.

With the access cover removed, the failed battery can be tested first by visual inspection and then by monitoring the individual cells. This procedure will result in information from which a decision can be made to repair or replace the battery.

For example, in this analysis it was assumed that battery replacement was required and that a spare battery was available. This necessitates that the Flight Commander reexamine the crew duty schedules. With a more precise estimate of maintenance time required to effect repair and the knowledge that two additional crew members will be required to assist, he can now schedule these activities.

With this decision made, the Operations Engineer begins removal of the failed battery (Task 012). The two crew members chosen to assist are notified and bring the spare to the installation area. The batteries are exchanged (Task 014/AA5) and the failed battery is placed in a marked container to ensure return to Earth for examination and determination of cause of failure (Task AA8).

After the battery has been replaced or repaired, the operating condition of the new battery is verified by visual inspection and by monitoring the cell and battery voltages (Task 017). The area is secured by replacing the battery access door, venting the battery compartment to space, and returning the instruction manual and tools to their proper locations.

A report is made to the Flight Commander who will decide when to switch the new battery into the system. This is accomplished by activating switches located on the control and display panel. Once back in the system, the battery will be placed on charge only and will not be used to supply loads until it is fully charged. Charging is accomplished during the light cycles, and will take up to three complete orbits if the battery was in a completely discharged condition. The battery will be checked regularly during charging. When a full charge is achieved, the battery charger will switch to a trickle charge mode. Therefore, full charge can be determined by monitoring the battery charger output.

After all batteries have reached full charge, normal operation of the loads and the crew can be resumed. IMCC is then notified that normal operation has been resumed.

9.2.5 RCS Engine Replacement

The nominal useful lifetime of a RCS engine on the MORL is approximately 1 year. If replacement of these engines is necessary, it would become a scheduled maintenance task. The activities associated with engine replacement were examined and are presented in an activity flow diagram, Figure 9-5. In this diagram, activities associated with sensing an engine condition where immediate replacement may be required are also presented to cover possible premature wear.

Accumulated engine burn time is the primary criterion used to establish whether or not an engine is fit to continue in service. After the accumulated time exceeds the allowable, replacement is required. The engine is shut down automatically and the redundant system is activated. If the automatic switching fails to activate, manual switching is provided (Task A11).

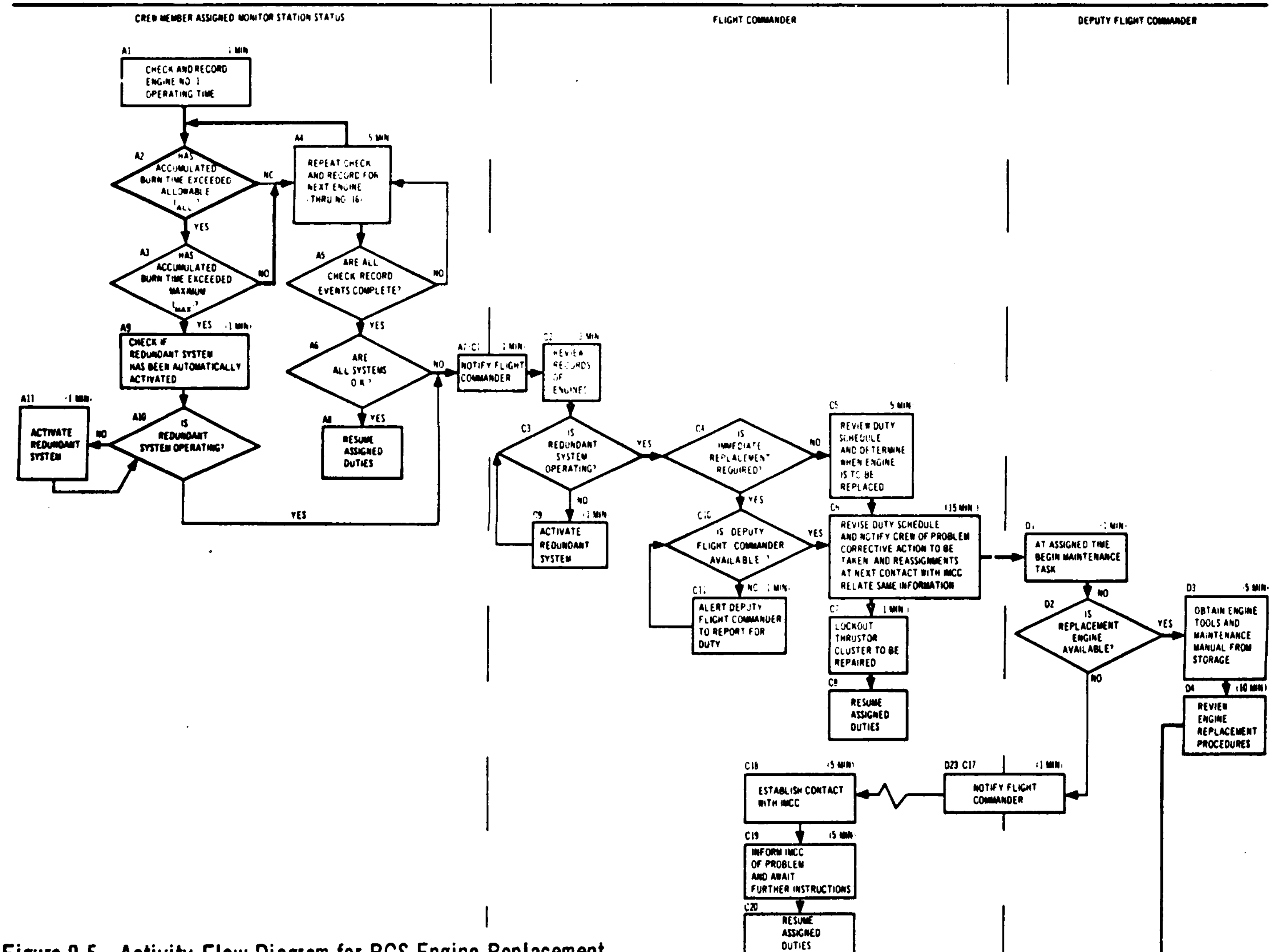


Figure 9-5. Activity Flow Diagram for RCS Engine Replacement

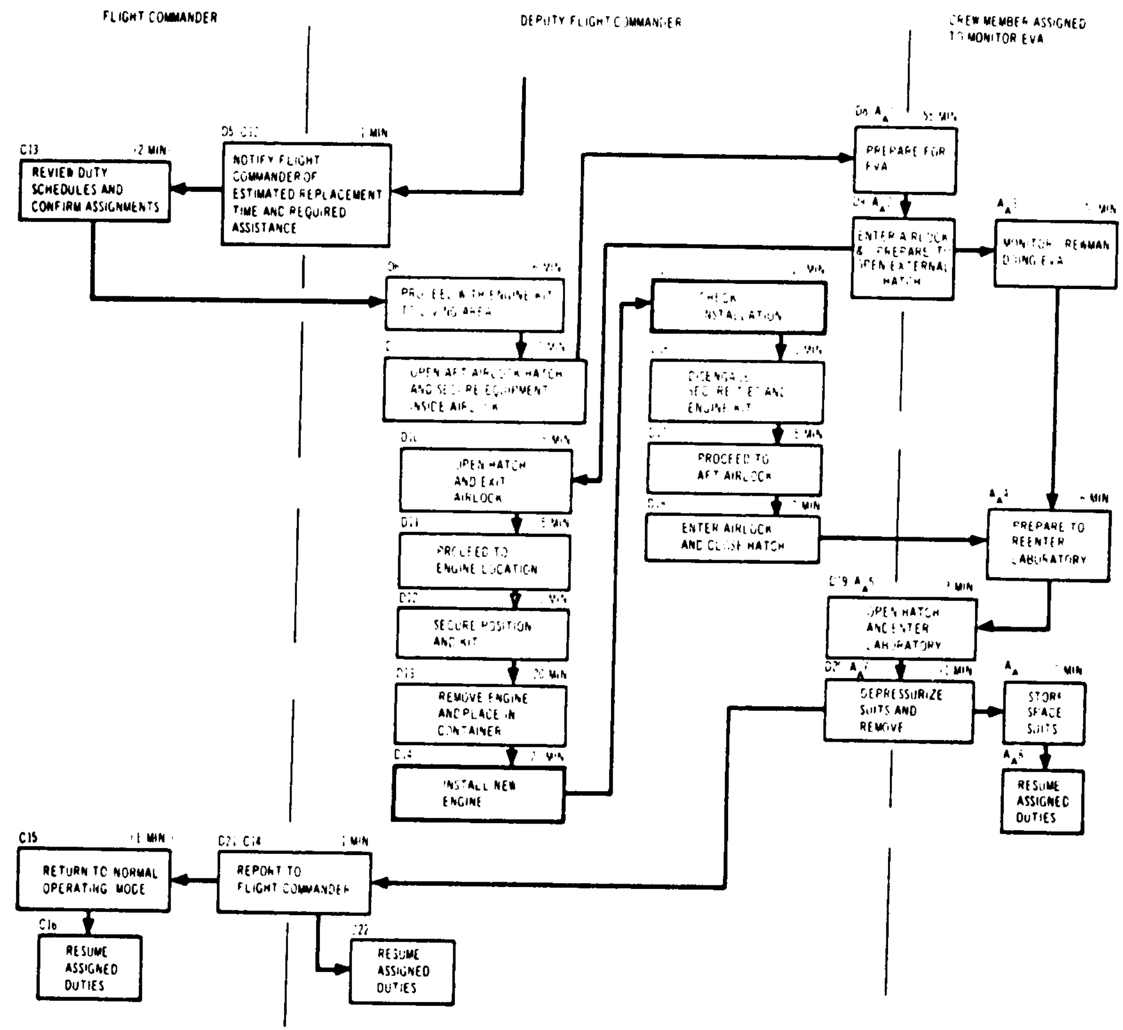


Figure 9-5. Activity Flow Diagram for RCS Engine Replacement (Continued)

The condition is reported to the Flight Commander who, after checking the engine records and redundant system operation, addresses himself to scheduling replacement activities. Since this task will involve an extravehicular operation, a minimum of two crewmen will be required. The Deputy Flight Commander has the qualifications and skills to effect repair and must be accompanied by a second crewman who is suited and stationed in the airlock to monitor the Deputy's status.

The thrustor cluster to be repaired would be locked out (Task C7) to ensure against accidental firing of these engines. After the necessary spares have been obtained and an estimate of time required for the operation is made from the maintenance manual, the Flight Commander can review duty schedules and make the appropriate reassignments.

Preparation for EVA includes donning space suits and denitrogenization (Task 08/AA1). The Deputy Flight Commander installs the replacement engine and performs an installation check in accordance with the maintenance procedure (Task D15).

After he returns he reports to the Flight Commander who can then return the laboratory to the normal operating mode.

9.2.6 Orbit-Keeping Operations

In the baseline MORL system, orbit-keeping operations are performed every 7 days. The required increase in velocity is computed at the IMCC and transmitted to the laboratory along with the specific time the operations are to be performed. The baseline concept of orbit keeping provides for two velocity addition events, 180° of orbit travel apart.

Figure 9-6 illustrates the events which take place on board the MORL. The activities are routine with only the added precaution of notifying the crew, (Task D3/A1) prior to firing the engines. Although the acceleration is very small, sensitive experiments or equipment are given added protection by being secured.

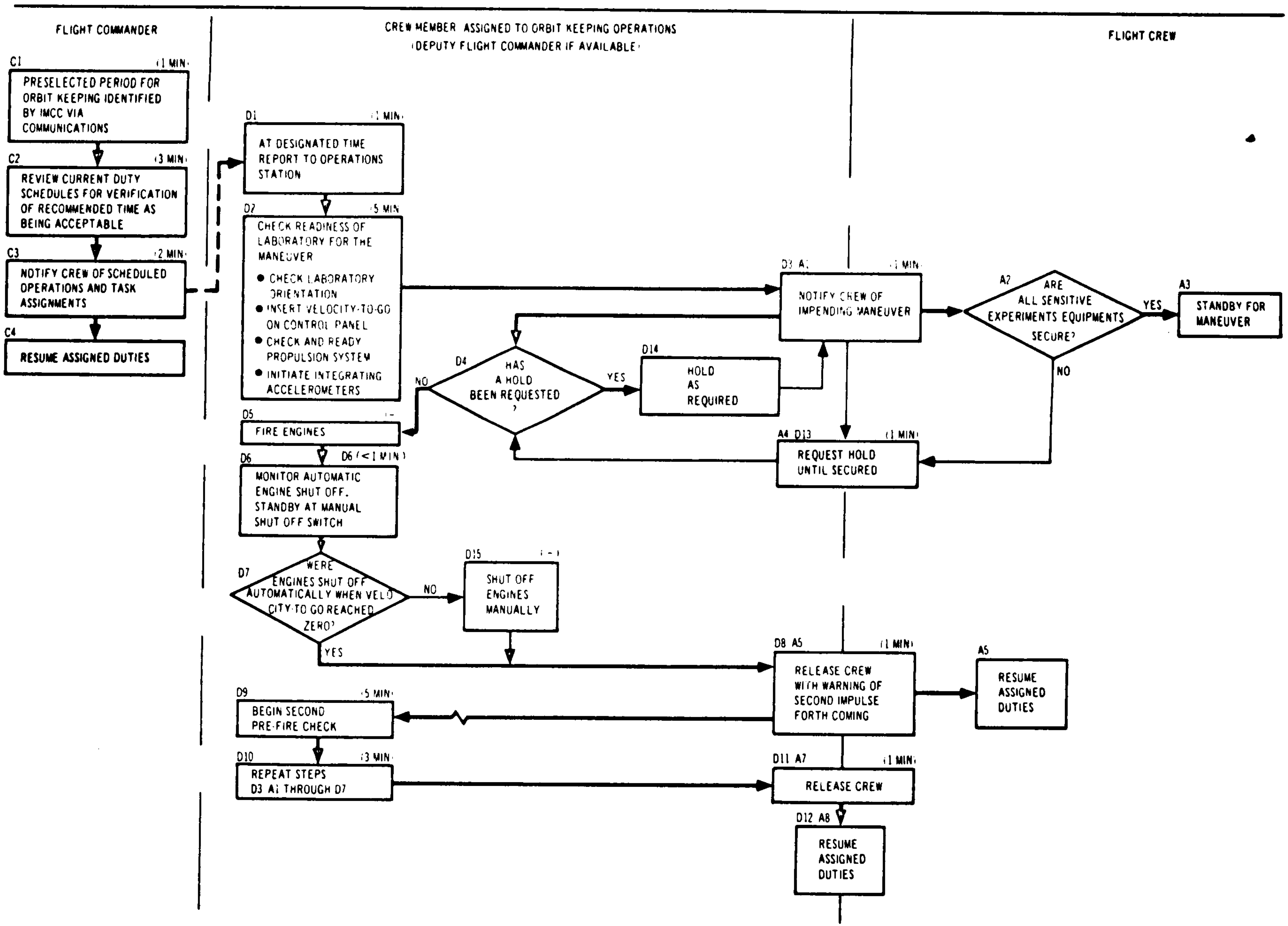


Figure 9-6. Activity Flow Diagram for Orbit-Keeping Operations

9.3 CONCLUSIONS

In Table 9-1, a summary of the results of the six disturbance analyses is presented. In the cases examined, the flight crew and the baseline MORL facility had sufficient capability to satisfactorily react to the disturbance, assuming the required spare was available. The indicated effect on the experimental program in progress, however, is that each event to some degree would cause an interruption of these activities. The interruption is caused primarily by the fact that more than one crew member (an average of three) becomes involved in each event. Generally, the three consist of the crewman who senses the failure or need for replacement, the Flight Commander who is responsible for the decisions which will affect subsequent scheduled activities, and the specialist who has the required skills to effect the repair.

Examination of the Time-Line Schedule, contained in the pocket attached to the rear cover of this report, indicates few opportunities during the 48-hour period where even the CO_2 level increase event (92 min. in duration) could be accomplished without affecting the schedule. On the other extreme the gyro failure, which has the longest elapsed time (about 12-1/2 hours), would at least interfere with the work/rest cycle of the crewman assigned to the maintenance task. The engine replacement event demands approximately 6 man-hours of crew time to effect repair.

It can be concluded that although approximately 18 man-hours of unassigned time (including contingency time) is available each day, the distribution of this time is such that any of the five maintenance events examined would result in the necessity to reschedule on-board activities. However, because the unassigned time is of that magnitude and is distributed fairly uniformly throughout each day, these perturbations would result in only minor scheduling changes, that is, shifting of time-insensitive experiments to the next opportunity.

Furthermore, it can be seen that sufficient unassigned time is available within each 24-hour period to accomplish the repair and return to the original schedule.

Table 9-1

PERTURBATION SUMMARY

Event	No. of Crewmen Involved	Specialist Required ?	Total Elapsed Time From Sensing to Repair(min.)	Commander Involved ?	EVA Required ?	Onboard Effect of Lack of Available Spare	Total Time Away from Other Duties (man-min.)	Remarks
CO_2 level increase	2	Yes	92	Yes	No	Shut down of hangar/ test area activities	63	Operate indefinitely using alternate system
C-Band transponder failure	3	Yes	246	Yes	No	Terminate oceano-graphic experiments	240	Reduced tracking accuracy. Need to guarantee avail-able spare.
CMG bearing failure	3	Yes	752	Yes	No	Use RCS to supplement SGCMG's	251	Increases propel-lant consumption--may expedite resupply
Battery failure	5	Yes	386	Yes	No	Reduce power loads when on dark side	145	Oceanographic experiments are all conducted on light side and power requirements decrease on dark side
RCS engine replacement	4	Yes	204	Yes	Yes	Continue operation until engine fails	349	Utilize redundant system until resupply
Orbit-keeping operations	2	No	60	Yes	No	N/A	39	The entire crew of six is involved. Although acceleration and resulting force acting on crew is small they must secure their positions
Average	3		290				181	

Some conclusions can be made regarding the effect of spare availability. For the five failure events examined, only one, the C-Band transponder failure, would result in a serious disruption of experimental activities if the necessary spare was unavailable. In this case, the tracking accuracy of the laboratory, as determined by the ground network, would be inadequate to support the oceanographic experiments under consideration. Since the effect would be severe in terms of money lost by the extensive support network (ships, instrumented range, and so forth), it becomes evident that the necessary spares should be guaranteed.

In the battery failure event considered, a 25% loss of power (1.5 kW) during the dark side of each orbit could disrupt all scheduled experiments during that time period because this approximately equals the 1.45 kW allotment for experiments. However, in the 48-hour period, all oceanographic experiments involving ocean measurements are conducted on the light side. Furthermore, examination of Figure 7-2, Electrical Load Profile, shows that the average demand is only approximately 200 of the 1,446 available watts and actual usage, discounting the peak demands, is even less. This amount could be supplied by using the 50% overload capability of the remaining three batteries until these experiments were rescheduled to be performed during the daylight side of the orbit. This would result in only a small schedule shift and probably would not interfere with the duty/rest cycles of the crew.

The inherent flexibility of the baseline system design with regard to spare unavailability is illustrated by the three other failures. In the case of the CO_2 level increase event, unavailability of the required spare would result only in an inconvenience to the flight crew. The laboratory proper could easily be operated using the hangar/test area purification system until the next resupply mission. In fact the hangar/test area could be re-entered to perform the photography experiment simply by switching back to the normal operating mode. This would provide pure atmosphere in the hangar and allow the laboratory atmosphere to increase in CO_2 level. After the experiment has been completed, switching could again be accomplished.

If the necessary gyro bearing spare parts are unavailable, two DGCMG's would be shut down. Attitude control would be accomplished using the two single gimballed CMG's supplemented by the reaction control system. This would result in higher propellant consumption, of course, but that may not be a problem if the supply is sufficient until the next resupply vehicle arrives. It may necessitate expediting the next logistics mission.

If there is no spare available to replace an RCS engine which has reached its allowable accumulated burn time limit, the engine could be used until that engine failed. Then, the redundant system would be used until the next resupply.

In summary, the following conclusions may be drawn:

1. Perturbations, such as those examined, would disrupt the predetermined schedule of on-board activities and, in particular, the experimental program.
2. Return to the schedule would be accomplished within a day's time because of the unassigned time (approximately 18 hours/day) available to accommodate perturbations such as these.
3. The Flight Commander is involved in every major perturbation. His schedule should contain a minimum of assignments, especially experimental, and a maximum of unassigned time.
4. The unavailability of spares necessary to effect repair is not critical to the survival of the laboratory or the flight crew; however, in at least one instance it may have a major effect on the experiment program.

9.4 RECOMMENDED FOLLOW-ON STUDIES

Two follow-on studies are recomended. These studies are as follows:

1. Investigate spare provisions for C-Band transponder. These spares should be of high priority.
2. Perturbation investigations such as these are valuable in determining specific limitations of the flight crew and facility capability. Examination of other failure modes would enhance the knowledge existing on this subject.

Appendix
EXPERIMENT DESCRIPTIONS

Section A-1
DESIGN EVALUATION AND APPROVAL TESTS OF FINAL RADAR EQUIPMENT
(Applications Plan Task No. 252)

A-1.1 PURPOSE

This experiment evaluates the capability of a radar to gather sea-state information by comparing the data to instrumented sea-surface measurements.

A-1.2 TASK DESCRIPTION

Members of the crew will be required to assemble and install the radar antenna on the external surface of the vehicle, and to install and calibrate the internally mounted equipment. After the equipment has been installed, members of the crew will operate the radar and collect synoptic data over preselected targets in the vicinity of the Continental United States. Necessary information, such as laboratory position in orbit, required antenna-pointing angles, and start and stop times, will be furnished to the crew from ground tracking facilities. The time necessary to install the equipment is reflected in the Day 1 crew time requirements noted below.

A-1.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: three
2. Skills:

Number	Name	Hours/Day 1	Hours/Day 2
11	Mechanical technician	4.36	None
12	Electromechanical technician	5.92	3.45
27	Observer	4.36	None

A-1.4 EQUIPMENT REQUIREMENTS

The equipment requirements are listed below:

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Radar system	220	6
1	Radar synchronizer	15	0.25
1	Operator console and display	20	0.97
1	Controller	15	0.25
1	Data recorder	20	0.50
1	Transmitter	27	0.66
1	Power supply	20	0.50
1	Antenna subsystem	70.4	1.167
1	Cable set	32	0.83

A-1.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The installation of the radar components located in the vehicle is restricted. The transmitter must be located close to the radar antenna to limit the rf transmission line to not more than 15 ft. The transmitter must also be at a close proximity to the receiver to avoid a receiver intermediate frequency (IF) cable length of more than 10 ft.

   Two ports through the bulkhead and skin of the laboratory will be required for the rf transmission line and for the power cable. The magnetic tape requires adequate facilities with proper control of temperature and humidity.

   The internal volume required to house the remainder of the equipment and the operator is approximately 14 cu ft.

   Since the radar antenna is externally mounted, an airlock is required to effect the installation. The external volume clearance required is a hemisphere with a radius of approximately 4.5 ft.

   The location of the radar antenna must be on the vehicle centerline and on the vertical axis and pointed in a generally downward direction. This allows the smallest sweep volume for antenna orientation.

2. Environmental Requirements

   A. The general environmental requirements are similar to those specified for the flight crew. For tape storage, it is necessary to provide humidity and temperature control within the following limits:

Relative humidity:	40% to 70%
Temperature:	$10^{o}C$ to $30^{o}C$

In addition, pressurization of the antenna feed system will be required.

B. An airlock is necessary to install the radar subsystem on the external surface of the spacecraft.

C. Except for magnetic tapes, no unusual storage requirements exist.

3. Data Requirements

A. Physical Data--The data output of the radar consists of a digital magnetic tape. The size of the reel of tape is 6 in. in diameter by 1 in. in width. This reel is capable of continuous recording of data for more than 1 hour, or three target runs. A total of 10 of these reels will be required.

B. Telemetry Data

(1) Parameter to be measured: Radar range to sea surface.

(2) Desired accuracy of measurement: ±1/2 ft.

(3) Type of signal: Digital.

(4) Minimum amplitude of signal: 1/2 V at tape recorder.

(5) Maximum amplitude of signal: 0.6 V at tape recorder.

(6) Time required for single measurement: 2.5 msec.

(7) Repetition rate: 2,000 bits/sec.

(8) Information content: Digital-coded range difference.

(9) Highest harmonic component of interest: Digital 5 kc; raw data 2 kmc.

(10) Maximum rise time of signal level change: Raw data 1/2 nanosec.

(11) Minimum duration of raw data signal: 1 nanosec.

C. Data Management--Extracting information from the digital tape will require processing of the magnetic tape to reformat the data for telemetry to Earth. A computer with 8,000 words of 12 bits/word or larger will be adequate.

4. Vehicle Performance--For best coverage of the ocean surface, an orbit-inclination angle of 60^{o} to 70^{o} is required. For early experiments for which an instrumented sea surface in the vicinity of the Continental United States seems most appropriate, 50^{o} is satisfactory.

The targets will be preselected consistent with orbit plots and must be adequately instrumented during measurement times. These targets are the Pacific Ocean at Hawaii, the North Atlantic Ocean, and the Caribbean Sea. In addition, fresh water bodies such as the Great Lakes may represent reasonably convenient targets.

The pointing accuracy of the radar requires that the line-of-sight of the stable platform of the vehicle be known within $\pm 0.1^{\circ}$ and have a stability which limits the drift in a 20-min. interval to $\pm 0.1^{\circ}$ or 0.3°/hour.

The position accuracy required is approximately $\pm 1/4$ ft and will require continuous ground track while the time measurements are being taken. Position stability (orbit stability) must be consistent during the same interval and the orientation so that the boresight is perpendicular to the surface of the Earth.

The time reference for measurement of radar range to the target requires an accuracy of 1 part in 10^7.

A-1.6 GROUND-SUPPORT REQUIREMENTS

The ground-support requirements for the radar experiment will include the following:

1. Adequate data transmission facilities from ground tracking to the equipment operator and radar equipment. This requirement stems from the necessity to accurately determine the position of the laboratory in orbit, to compute the required antenna pointing angles, and to start and stop times for the radar automatic programmer. These data will then be relayed to the radar operator for each data-taking orbit.
2. Instrumentation of portions of the sea surface will be required at points designated as radar targets. The measured value of sea-state or wave height will be correlated with measurements from the laboratory during data evaluation. Instrumentation may be accomplished in a variety of ways, for example, airborne radar, buoys, or ships at sea. These data will be time referenced and location referenced for data entry when comparisons are to be made.
3. A calibrated preprogrammed ground-based transponder will be required to furnish additional data. These data will be in the form of absolute range data, range differential accuracy, and information useful in evaluating effects of atmospheric refraction of the radar line of sight.

Section A-2

DESIGN EVALUATION AND APPROVAL TESTS OF VARIABLE FOCAL-LENGTH, HIGH-SPEED, LARGE-FORMAT CAMERA

(Applications Plan Task No. 255)

A-2.1 PURPOSE

The purpose of this experiment is to (1) verify the utilization of both black and white photography for locating and identifying surface plankton concentration, and (2) to investigate the possibility of inferring quantitative estimates of concentrations. Photographic developing of film and film analysis will be included as part of this task.

A-2.2 TASK DESCRIPTION

The installation of equipment for conducting the photography experiment will be accomplished in and on the instrumentation airlock. The operator will be required to unpack and to set up the camera body; to change lenses, filters and film; to insert and record data; and to process and analyze the film. Position and alignment data will be transmitted to the laboratory from the ground. Film processing time is reflected in the crew time requirements for Day 2 noted below.

A-2.3 CREW TIME AND SKILL REQUIREMENTS

The following are crew time and skill requirements:

1. Number of men required: three
2. Skills:

Number	Name	Hours/Day 1	Hours/Day 2
8	Photo technician/ cartographer	4.1	17.5

A-2.4 EQUIPMENT REQUIREMENTS

The following are equipment requirements:

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Camera body with integral f-stop and shutter assembly (manual and automatic)	10	1
1	Photometer	1	0.00695
1	Film pack	10	1.15
1	Lens and filter kit	0.45	2.57
1	Contrast plate and data reversal mirror	1	0.0185
1	Gimbal frame and drive (aiming mechanism)	30	5.9
1	Data input and mission monitor console	8	0.278
1	Optical dome	177	0.885
1	Programmer	10	0.125

A-2.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The installation of equipment for the photography experiment will be accomplished in and on the instrumentation airlock as previously specified in Douglas Report No. SM-46074, Volume III, System Analysis, Experimental Program. An optical dome, secured in the extender frame of the airlock, will be required to provide an optically suitable aperture through the laboratory wall for conduct of the experiments. The dome should be amenable to installation in the extender frame and be hemispherically shaped, high-quality optical glass. A gimbal frame and drive assembly (aiming mechanism) will be mounted in the airlock so that, when the camera is mounted in the assembly, it will be capable of looking through the dome at angles from the normal (to the dome) to 8° or 10° off the axis in any direction. By positioning the focal point of the camera system at the center of the dome base, nondistorted target views can be obtained throughout the full range of aiming adjustment.

   The gimbal frame and drive assembly should be pin locked and vernier adjusted to a constant reference line on the airlock rim. The X and Y drives for the system can then be accurately referred to any convenient axes, such as those of the laboratory. The 8° to 10° allowable adjustment of the system will sweep out targets up to 40 mi off the centerpoint of the system.

The camera system should be similar in concept to the Swedish Hasselblad--a separate body, lenses, film packs, and accessories. Several lenses may be desired but the preferred unit will be a 70-in. telephoto lens folded down into a physical length of 24 in. A look angle of 8° will then result in an image suitable for matching the 9 x 9-in. film format.

Storage lockers for lenses, filters, and the film pack should be located within easy access of the airlock. The control console should be adjacent to the installed system. A power and control cable will run from the system assembly to a point near the control console.

The instrumentation airlock will meet requirements for apertures in the laboratory relative to conduct of this experiment. The field of view measured from the base center of the dome should be a cone of 30° around the long axis of the airlock.

No special hardware storage and handling requirements exist. However, extreme care should be observed in moving pieces of the system equipment because alignment of the components is highly critical and could be affected by slight bumps or jarring.

The total volume required for the installed system will be the volume of the airlock plus two additional feet above the interior rim (excluding extra film pack storage space).

The processing and analyzing of film exposed during the experiment will be accomplished in the darkroom of the photographic facilities. Special requirements include the compatibility of Exp-255 films with the furnished equipment and facilities to handle both color and black and white processing simultaneously.

2. Environmental Requirements

A. The general environmental requirements are similar to those specified for the flight crew. In the case of film storage, humidity and temperature control should be provided within the following limits:

Relative humidity:	40% to 70%
Temperature:	$10^\circ C$ to $30^\circ C$

The film should be shielded from radiation, and all components should be well protected against shock.

B. The instrumentation airlock and the darkroom facilities are required for this experiment.

C. The requirements, as defined in Items A and B, are applicable both in terms of shock protection for hardware, and for temperature, humidity and radiation protection for film. Protection against wide temperature and pressure excursions will also be required for optical elements.

3. Data Requirements

A. Physical Data--The physical form of the data output of photography is regular photographic film (positive transparencies). The size of the reel is 10 in. in diameter and contains 120 frames of 9 x 9 in. format. At a 10 mi coverage per frame, a single reel will cover 1,200 continuous miles of strip photography or an equivalent amount in any desired combination of strips and single shot. A total of 20 reels (10 color and 10 black and white) will be adequate for the experiment.

B. Telemetry Data--It does not appear to be within the current technology to transpose the film transparencies to digital form with sufficient resolution to permit a useful reformation of the original image for analysis on the ground. Should these data be required prior to physical re-entry of films, an analysis on a frame-by-frame basis will be required on board the laboratory. A data format would then be required which, through a minimum number of bits (several hundreds/frame), could identify parameters of significance to the experiments. These parameters will include target identification, density abnormalties and gradation, spectral distribution plots from color-patch matching, and area coverage of detectable plankton concentration. If analysis of any frame yields a negative result, then the data for that frame are reduced to identification only. There is no requirement for real-time transmission, and the actual total transmission time of the accumulated data is not of significant impact to the normal provisions for data telemetry.

C. Data Management--The on-board processing will include development of the films and a frame-by-frame analysis to assign meaningful parametric values to the features of apparent interest. These values must be consistent with the specified data format and can be programmed for transmission on punched cards or paper tape for later transfer to standard magnetic tape.

4. Vehicle Performance--For the best coverage of the ocean surface from which synoptic data are collected, an orbit-inclination angle of 60° to 70° is required. However, 50° will suffice for the early experiments which are designed to demonstrate feasibility.

The targets have been preselected consistent with orbit plots and include those off-shore areas of the Continential United States where concentrations of living organisms are likely to be found. Because the desired target coverage for this experiment is 10 x 10 mi, the line of sight for aiming should be known with respect to the vehicle's stable platform to within $\pm 0.1^\circ$ and should have a stability which limits the drift in a 20-min. interval to $\pm 0.1^\circ$ or 0.3°/hour. The camera assembly will be aimed by an automatic system with a closed servo loop, with the laboratory inertial platform providing the attitude reference.

During each mission preparation period, orbit data such as laboratory track position and attitude will be updated by the ground station. This information, when added to the target geographic coordinates, will enable aiming data; target times will be processed by the automatic programmer which, in turn, will cause the system to function properly.

The position accuracy required is approximately ±1/4 ft and will require determination at each orbit updating. Position stability must be consistent during the target observation time.

The time reference during the photography experiment must be accurate to within 0.1 sec.

The attitude of the laboratory during the experiment must be such that the instrumentation airlock is boresighted on the ground-orbit trace to within $\pm 5^{\circ}$.

A-2.6 GROUND-SUPPORT REQUIREMENTS

1. Adequate data transmission facilities from ground tracking to the equipment operator. This requirement stems from the need to accurately prescribe the position and attitude of the laboratory in orbit and to compute the required camera aiming angles and start-stop times for the automatic programmer. These data will then be relayed to the photographic operator for each data-taking orbit.
2. Instrumentation in the nature of meteorological (radiosonde) balloons is required to permit ground-based optical tracking of these balloons and determination of the atmospheric optical transmission properties over the target areas at the time of data collection. This may be accomplished from ships at sea, airborne platforms, or ground stations. The data will be time referenced and location referenced for data entry when comparisons are to be made during ground analysis of film transparencies after transporting them to Earth.

Section A-3
DESIGN EVALUATION TESTS OF MICROWAVE RADIOMETERS
(Applications Plan Task No. 256)

A-3.1 PURPOSE

This experiment will verify the capability of a two-frequency microwave radiometer to determine the temperature profile at the surface layer of the sea. The temperature profile provides a measure of the heat interchange at the sea surface.

A-3.2 TASK DESCRIPTION

The crew members will be required to assemble and install two antennas on the outside of the vehicle as well as to install and calibrate the internally mounted equipment. Following setup, the crew members will operate the radiometer and collect synoptic data over preselected targets in the vicinity of the Continental United States. Equipment installation time is not reflected in the crew time requirements noted below.

A-3.3 CREW TIME AND SKILL REQUIREMENTS

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day 1	Hours/Day 2
12	Electromechanical technician	1.8	None

A-3.4 EQUIPMENT REQUIRED

Quantity	Item	Weight (lb)	Volume (cu ft)
1	4-wave radiometer system	83	1.9
1	Operator console and display	15	0.75
1	Controller	4	0.0625
1	Data recorder	20	0.5

Quantity	Item	Weight (lb)	Volume (cu ft)
1	K-band antenna assembly	10	0.0625
1	S-band antenna assembly	10	0.0625
1	Power supply	4	0.0833
1	Cable set	20	0.375

A-3.5 OPERATIONAL REQUIREMENTS

1. Equipment Installation Requirements--The installation of the two-frequency microwave radiometer components inside the vehicle is not critical, with the exception of the normal constraint of keeping cable length reasonably short. Two ports will be required through the bulkhead for the power and signal cables for each antenna. Proper control of temperature and humidity will be required for the magnetic tapes.

   Since the two-frequency microwave radiometer is mounted outside the vehicle, an airlock is required to effect the installation. The location of the antenna assembly must be on the vehicle centerline and on the vertical axis to be pointed in a generally downward direction.

2. Environmental Requirements

   A. General environmental requirements are similar to those required by the flight crew. For tape storage, humidity and temperature control is required within the following limits:

      Relative humidity: 40% to 70%

      Temperature: 10^{o}C to 30^{o}C

   B. An airlock is necessary to install the two-frequency microwave radiometer antenna subsystem outside the laboratory.

   C. No special storage requirements exist with the exception of tape storage as indicated above.

3. Data Requirements

   A. Physical Data--The physical form of the data output of the two-frequency microwave radiometer is digital magnetic tape. The size of the reel is 6 in. in diameter by 1 in. in width with a capacity for continuous recording of the two-frequency microwave radiometer data for 1.25 hours over a 48-hour period. For a 1^{o} beamwidth, the data rate will be approximately 200 bits/sec and, therefore, only one such reel will be required.

   B. Telemetry Data

      (1) Parameter to be measured: ocean surface temperature.

      (2) Desired accuracy of measurement: $\pm 0.1^{o}$C.

      (3) Type of signal: digital.

(4) Minimum amplitude of signal: 1/2 V at tape recorder.

(5) Maximum amplitude of signal: 0.6 V at tape recorder.

(6) Time required for single measurement: 100 msec for 1° beamwidth system.

(7) Information rate: 200 bits/sec.

(8) Information content: digital coded temperature.

(9) Highest harmonic component of interest: digital 300 cps.

C. Data Management--The magnetic tape will be processed to reformat the data for telemetry to Earth. A computer with 1,000 words of 9 bits/word memory storage will be adequate.

4. Vehicle Performance--For best coverage of the ocean surface from which synoptic data are to be collected, an orbit inclination of 60° to 70° is desirable. However, for initial radiometry experiments, a 50° inclination angle is satisfactory, since it is desired to conduct experiments which can be correlated with surface measurements for regions of the sea in the vicinity of the Continental United States.

The pointing accuracy requirements for the antenna assembly with respect to the vehicle stable platform will depend upon the beamwidth designed into the antenna system. If a 1° beamwidth is used, then a pointing accuracy with respect to the vehicle stable platform of 0.1° with a drift not exceeding 0.3°/hour would be satisfactory. On the other hand, if an order-of-magnitude increase in resolution is desired, then more severe constraints will have to be placed on pointing accuracy and drift stability. The temperature measurement requirements have been specified as being stable within the temperature resolution interval of $0.1^\circ C$ and cover a range of at least $-5^\circ C$ to $+35^\circ C$.

A-3.6 GROUND-SUPPORT REQUIREMENTS

The ground-support requirements for the radiometry experiments will provide temperature measurements of the sea surface at those points which are designated for temperature measurement from the laboratory. This surface-measured value of ocean temperature will be correlated with measurements from the laboratory during data evaluation. This instrumentation may be accomplished by buoys or ships at sea. The data will be time-referenced and location-referenced for data entry when comparisons are to be made. Ancillary data will have to be provided on atmospheric conditions and on cloud cover in the final data evaluation.

Section A-4
DESIGN EVALUATION TESTS OF INFRARED RADIOMETER
(Applications Plan Task No. 257)

A-4.1 PURPOSE

The purpose of this experiment is to evaluate the performance of an IR radiometer in measuring sea-surface temperature by comparing the data with directly measured sea surface values.

A-4.2 TASK DESCRIPTION

The crew members will be required to assemble and install the IR sensor on the outside of the vehicle and install and calibrate the internally mounted equipment. Following setup, members of the crew will operate the radiometer and collect synoptic data over preselected targets in the vicinity of the Continental United States. Equipment installation will be conducted prior to the 1-day experiment period. Equipment installation time is not reflected in the crew time requirements noted below.

A-4.3 CREW TIME AND SKILL REQUIREMENTS

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day 1	Hours/Day 2
14	Optical technician	2	1.7

A-4.4 EQUIPMENT REQUIREMENTS

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Infrared radiometer system	66	1.9
1	Operator console and display	15	0.75
1	Controller	2	0.03125
1	Data recorder	20	0.50

Quantity	Item	Weight (lb)	Volume (cu ft)
1	IR sensor unit	5	0.125
1	Optics assembly	6	0.145
1	Power supply	4	0.0833
1	Cable set	14	0.25

A-4.5 OPERATIONAL REQUIREMENTS

1. Equipment Installation Requirements--The installation of infrared components that are located inside the vehicle is not critical. The configuration of equipments can be rearranged if this will provide any advantage for interfacing with other laboratory equipment.

   One port through the bulkhead will be required for a cable which contains the power supply and the sensor leads.

   The use of magnetic tape requires adequate facilities with proper control of temperature and humidity.

   Since the infrared radiometer telescope and sensor are mounted outside the vehicle, an airlock is required to effect the installation. The location of the telescope sensor assembly must be on the vehicle centerline and on the vertical axis in order to point in a generally downward direction.

2. Environmental Requirements

   A. The general environmental requirements imposed by the presence of man on the laboratory are generally satisfactory for the equipment. In the case of tape storage, it is necessary to provide humidity and temperature control within the following limits:

      Relative humidity: 40% to 70%

      Temperature: 10°C to 30°C

   B. An airlock is necessary to install the telescope and infrared sensor subsystem external to the spacecraft.

   C. General storage requirements are the same as these required by man's existence in the same environment with the exception of tape storage as indicated in Item 2A above.

3. Data Requirements

   A. Physical Data--The physical form of the data output of the infrared system is digital magnetic tape. The size of the reel is 6 in. in diameter by 1 in. in thickness and contains capacity for continuous recording of the infrared data for 2 hours and 30 min. over a 48-hour period. For the 1° field-of-view system the data rate will be approximately 100 bits/sec, and, therefore, only one such reel will be required.

B. Telemetry Data

(1) Parameter to be measured: ocean surface temperature.

(2) Desired accuracy of measurement: $\pm 1^{\circ}C$.

(3) Type of signal: digital.

(4) Minimum amplitude of signal: 1/2 V at tape recorder.

(5) Maximum amplitude of signal: 0.6 V at tape recorder.

(6) Time required for single measurement: 100 msec for 1° field-of-view system.

(7) Information rate: 100 bits/sec.

(8) Information content: digital coded temperature.

(9) Highest harmonic component of interest: digital 300 cps.

C. Data Management--The extraction of information from the digital tape will necessitate processing the magnetic tape to reformat the data for telemetry to the ground. A computer with 1,000 words of 9 bits per word memory storage will be adequate.

4. Vehicle Performance--For best coverage of the ocean surface from which synoptic data are to be collected, an orbit inclination of 60° to 70° is desirable. For early infrared temperature measurement experiments, a 50° inclination angle is satisfactory, since it is desired to conduct experiments which can be correlated with the surface measurements for regions of the sea in the vicinity of the Continental United States.

The pointing accuracy requirements for the infrared telescope assembly with respect to the vehicle stable platform will depend upon the field of view designed into the telescope sensor assembly. If a 1° field of view is postulated, then a pointing accuracy with respect to the vehicle stable platform of 0.1° with a drift not exceeding 0.3°/hour would be satisfactory. On the other hand, if an order-of-magnitude increase in resolution is desired, then more severe constraints will have to be placed on pointing accuracy and drift stability. The temperature measurement requirements have been specified as stable within the temperature resolution interval of $0.1^{\circ}C$; they cover a range of at least $-5^{\circ}C$ to $+35^{\circ}C$.

A-4.6 GROUND-SUPPORT REQUIREMENTS

The ground-support requirements for the infrared experiments consist primarily of providing temperature measurements of the sea surface at those points which are designated for infrared measurement from the laboratory. This surface-measured value of ocean temperature will be correlated with measurements from the laboratory during data evaluation. This instrumentation may be accomplished by buoys or by ships at sea. The data will be time-referenced and location-referenced for data entry when comparisons are to be made. Ancillary data will have to be provided on atmospheric conditions and on cloud cover in the final data evaluation.

Section A-5
COSMIC DUST MEASUREMENT
(Data Bank Experiment No. IA-1)

A-5.1 PURPOSE

The purpose of this experiment is to measure meteoroid impact rates and momentum during the life of the laboratory. The results would permit a better evaluation of the hypothesis of the continuous generation of dust caused by disintegration of conglomerates of interplanetary material. Additionally, these measures would provide information on the effects of meteoric showers on metallic structures during a prolonged exposure.

A-5.2 TASK DESCRIPTION

The crew will be required to unpack, assemble, checkout, and calibrate the sensing equipment. They will then install the sensors extravehicularly and initiate the testing operations. Calibration checks will be performed approximately every 2 weeks. Crewmen will change the orientation of the panels and inspect the panels once per month. Mast and swivel changes will be required daily, during the tests. In addition, amplifier sensitivity must be adjusted periodically. This can be accomplished from inside the laboratory. Repair will be normally accomplished by substituting a complete detector assembly, motor, or motor control.

A-5.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day
12	Electromechanical technician	0.25

A-5.4 EQUIPMENT REQUIRED

The equipment requirements are listed below:

Quantity	Brief Description	Weight (lb)	Volume (cu ft)
4	Detector array, frame, and mast with control motor and cables	60	32.0
12	Sounding boards (piezvoelectric transducers, amplifiers, and external cables)	37	13.5
12	Lucite blocks with photo multiplier unit, amplifier, and external cables	7	1.0
	Internal cable set	3	0.5
	Totals	117	47.1

A-5.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--Data channels, control panels, and audible alarms are installed internally before launch or as part of the general preparation for the measurement activity in flight. Swivel and mast-drive motors are part of the mast assembly and installation which is considered an external operation. The mechanical position readout incorporated into the mast and swivel assemblies is also part of the external operation.

   Externally mounted equipment includes the detector array and mast assembly with drive motors, cables, and position readouts.

2. Environmental Requirements--The detectors should not be shaded by crewmen during extravehicular activity or by other equipment. Normal care, similar to that required for packaging and handling fragile equipment, will be necessary in preparing materials for shipment. There are no special external environmental requirements. Finally, there are no special storage requirements. Spares will be stored in original resupply packages.

3. Data Requirements--No data samples will be returned to Earth unless the sensitivity of the sensors needs to be correlated and calibrated with telemetered data. It is assumed that sensor output amplitude

and duration will be significant. These parameters may be converted to digital, stored with other pertinent data, and transferred to the telemetry subsystem.

The following requirements exist for telemetry data:

A. Sensors.

(1) 8 photomultipliers, 8 sounding boards: 16 analog signals.

(2) Vehicle position and attitude: 6 analog signals.

(3) Panel orientation: 6 analog signals.

B. Sampling Rate.

(1) Average hit rate: 3/min.

(2) Maximum: 5/sec.

(3) Record for each hit:

Panel number.

1 photomultiplier output.

1 sounding board output.

9 position and orientation channels.

Time (within 20 sec).

C. Sampling Period: Intermittent when hit occurs.

D. Accuracy: 1%

E. Data

(1) Average: 376,000 bits/day.

(2) Storms: 3,760,000 bits/day.

There is no requirement for data management beyond involvement in tagging data with time, sensor number, etc., unless programming of data sampling can improve efficiency of acquisition of data from sensors. All data acquired from sensors are of interest to ground analyzers; therefore, on-board data reduction probably will not be required.

4. Displays and Controls--Displays and controls are as follows:

A. Mast and array swivel display.

B. Mechanical vernier readout at each mast port.

C. Signal monitor (operations panel).

D. Computer and manual motion controls at each part for mast and swivel motors.

5. Vehicle Performance--Special performance requirements are not anticipated unless specific laboratory orientation is required during storm. Information on laboratory orientation and position must be available, however, for later correlation of data.

A-5.6 GROUND-SUPPORT REQUIREMENTS

Storm alerts will, in some cases, originate from the ground and may induce periodic requests to inspect the array and check the calibration.

Section A-6

EFFECTS OF HIGH-ENERGY PARTICULATE RADIATION ON SELECTED LIVING AND NONLIVING MATERIALS

(Data Bank Experiment No. IB-23)

A-6.1 PURPOSE

This experiment will measure the effects of solar and cosmic high-energy particulate radiation on selected living and nonliving organic materials and to determine how the functional performances of these materials are modified for point defects, dislocations, and other material damage forms, scissions, random growth, steep time-exponential growth, solidification, and loss of living functions of biopolymers.

A-6.2 TASK DESCRIPTION

Three sets of samples would be stored and exposed for the life of the laboratory under the following conditions:

1. One set in a flight-mounted storm cellar within the laboratory.
2. One set exposed to the laboratory internal environment.
3. One set exposed to the external space environment.

The crew members would be required to mount the specimens in the appropriate storage racks and to take daily notes on changes in the observable specimens.

A-6.3 CREW TIME AND SKILL REQUIREMENTS

The following are crew time and skill requirements:

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day 1	Hours/Day 2
12	Electromechanical technicians	0.25	0.25

A-6.4 EQUIPMENT REQUIRED

Quantity	Brief Description	Weight (lb)	Volume (cu ft)
1	Storm cellar	45	0.44
225	Test specimens	74.4	4.68
2	Exposure rack	6	0.30

A-6.5 OPERATIONAL REQUIREMENTS

The operation requirements are as follows:

1. Equipment Installations Requirements--The internal exposure rack with test specimens can be mounted in any desired area of the laboratory. Precautionary measure must be taken to protect the crew in case the quartz tubes break accidentally.

   The external exposure rack should be mounted close to the airlock for easy access. An observation window would be desirable for the daily checking of the specimens.

   A storm cellar storage container would be mounted externally, in any desired location, during the life of the laboratory.

2. Environmental Requirements

   A. The normal shirtsleeve environment of the vehicle will be required for the storage areas of both the specimens, whether in open storage or in the storm cellar.

   B. The airlock will be required to load the specimens on the external exposure rack at the start of the experiment and to remove the specimens at the termination of the experiment.

   C. The storm cellar specimens will not be touched from the time of launch until the final abandonment of the laboratory.

   D. The other specimens will require special packaging for flight.

3. Data Requirements--Daily notes will be taken on (1) changes in the appearance of the observable specimens and (2) the loss of any specimens should this occur.

4. Displays and Controls--No additional displays and controls are required.

   e. Vehicle Performance--No special vehicle performance is required.

A-6.6 GROUND-SUPPORT REQUIREMENTS

No special ground support is required.

Section A-7
MEASUREMENT OF SOLAR ABSORPTIVITY AND THERMAL EMISSIVITY OF VARIOUS MATERIAL BY SPECTROMETRY
(Data Bank Experiment No. IIIB-6)

A-7.1 PURPOSE

The purpose of this experiment would be to determine the physical variables which cause changes in the ratio of solar absorptivity to thermal (infrared) emissivity in various materials after prolonged exposure to the orbital environment.

A-7.2 TASK DESCRIPTION

The general procedure for this experiment is to expose selected metal and coated-metal specimens to the space environment and then periodically to determine the total thermal emittance and total solar absorbtance by calorimetric measurements. The specimens, or parts of each specimen, will be brought into the laboratory for spectral reflectance measurements and for physical and chemical analyses. The crew members would then return the specimens to the external racks for further exposure. Sections from the specimens may be sent periodically to Earth for further analysis.

A-7.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day
12	Electromechanical technician	0.1

A-7.4 EQUIPMENT REQUIRED

The equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Camera and color film	1	0.5
1	Spectrophotometer thermocouples	18 Neg	1.0 Neg
1	Recorder	Neg	Neg
1	Sample carrier	2	0.25
	Samples	Neg	Neg
	Totals	36.0	2.25

A-7.5 OPERATIONAL REQUIREMENTS

1. Equipment Installation Requirements--The recording equipment and reflective measuring equipment devices may be located at any convenient place in the laboratory. No specific orientation is required for the equipment. One port must be available to provide access to the experiment rack holder. The port need not be oriented to the vehicle centerline with respect to body axes. No special storage requirements, assembly requirements of subcomponents, or operation volumes are required.

   The external sample holders should be oriented so that the samples face the Sun during part of the orbit and do not face either the Sun or the Earth during part of the orbit.

2. Environmental Requirements--No unique environmental requirements are necessary for the recording and measuring equipment.

3. Data Requirements--The test panels will be returned to Earth for further analysis.

   The main parameter will be measured in optical reflectivity as a function of wave length. The data will be recorded on strip charts and the observations made by the crew members will be recorded in an experiment log book.

4. Displays and Controls--Displays will consist of strip charts and readings of sample temperature, of heating and cooling, and of reflectometer light intensity and wavelength.

5. Vehicle Performance--No special vehicle performance is required by the experiment.

A-7.6 GROUND-SUPPORT REQUIREMENTS

There are no ground-support requirements beyond normal support.

Section A-8

SPACE VEHICLE EQUILIBRIUM STUDY

(Data Bank Experiment No. 1C-15)

A-8.1 PURPOSE

This experiment will determine the effectiveness of thermal analysis methods used in the design of environmental control systems.

A-8.2 TASK DESCRIPTION

The crew is required to note (on tape) their level of activity during specified periods and its influence on the thermal conditions in the vehicle. Various levels of activity will be observed and the crew members may adjust various ECS controls to obtain data for unusual situations. The data will be recorded automatically.

A-8.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day
11	Mechanical Technician	0.2 av

A-8.4 EQUIPMENT REQUIRED

Quantity	Item	Weight (lb)	Volume (cu ft)
25	Thermocouples and associated wiring	5	0.1
1	Voice tape recorder	13	0.2

A-8.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The thermocouples would be installed on the ground and would be distributed throughout the vehicle structure. Readouts would be connected to the data management system.

2. Environmental Requirements--There are no special environmental requirements.

3. Data Requirements--Data recorded from the temperature sensors, the environmental control system, and the crew observations will be telemetered to the ground for reduction and analysis.

4. Displays and Controls--No special display and controls are required.

5. Vehicle Performance--No special vehicle performance is required.

A-8.6 GROUND-SUPPORT REQUIREMENTS

Ground crews will reduce and analyze data gathered during the tests.

Section A-9
EVALUATION OF COMMUNICATION TECHNIQUES
(Data Bank Experiment No. IIC-1)

A-9.1 PURPOSE

The purpose of this experiment is to improve communications techniques by investigating the problems and physical phenomenon associated with communications from spacecraft to Earth, from Earth to spacecraft, from spacecraft to spacecraft, from spacecraft to aircraft, from logistics vehicle to Earth, and from ground to ground.

A-9.2 TASK DESCRIPTION

Principally, the crew members would participate in the experiment by setting up appropriate receiving equipment configurations and selecting data to be transmitted to Earth. The bulk of the crew's time will be spent in checking equipment and in sorting results of the various tests.

A-9.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day
17	Microwave specialist	1.3

A-9.4 EQUIPMENT REQUIRED

The equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Amplifier	3	0.3
1	Receiver	30	2.5
1	Converter	3	0.3

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Spectograph	30	1.5
1	Antennas	100	4.5
1	Magnometer	10	0.2

A-9.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--All equipment, except for the antenna, is mounted inside the vehicle in proximity to each other. Space for the equipment should be provided close to the experimental console.

   The antenna is mounted outside of the vehicle. It is unfurled into a long diopole in the active state.

2. Environmental Requirements--There are no special environmental requirements.

3. Data Requirements--The types of data samples to be returned to Earth include ionograms from spectrograph, taped ionograms, and noise maps. For the ionograms, a 10 kc analog telemetry data channel is required.

   The only data management requirement is the selection of materials (ionographs and noise maps) for transmittal to the ground. The most important results could be transmitted by television.

4. Displays and Controls--The ionograms will be displayed on the spectograph. Controls are of the on-off type.

5. Vehicle Performance--The location of the vehicle at the time of the tests should be at various distances from the ground station for the sounding experiment.

A-9.6 GROUND-SUPPORT REQUIREMENTS

Support from the ground will include transmitting hf signals and receiving sounding signals.

Section A-10
FATIGUE TESTS OF MATERIALS AFTER EXPOSURE TO SPACE ENVIRONMENT
(Data Bank Experiment No. IIIB-3)

A-10.1 PURPOSE

The purpose of this experiment is to measure the mechanical properties of elastic materials, particularly metals, after long-term exposure to the space energy spectrum.

A-10.2 TASK DESCRIPTION

The crew will install one testing machine extravehiclularly so that some tests can be run in the external environment. In addition, the crew will mount the metallic specimen in various positions on the external skin of the laboratory. They will periodically retrieve some specimens for testing inside the laboratory. Other specimen will be vacuum-bottled and returned for testing in the Earth environment. External testing can be manually controlled from inside the laboratory. The crew will also visually inspect specimen. Data recording of results and observations will be required during the testing procedures.

A-10.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day
11	Mechanical technician	1

A-10.4 EQUIPMENT REQUIREMENTS

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Testing machine	70	2
1	Metallic specimens	1	neg

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Timer	0.5	0.01
1	Temperature recorder	5	0.1

A-10.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The timer used to determine the time-to-rupture of the test coupons should be mounted as part of the experiment control console. The temperature and pressure recorders required to record the specimen temperature and surrounding pressure history should also be mounted on the experiment control console.

   The testing machine will be mounted in the equipment airlock and sealed so that the test-coupon side of the mounting plate is exposed to the space environment while the motor side is exposed to a pressurized atmosphere.

2. Environmental Requirements--No special environment is required within the laboratory. Test samples need to be exposed to the vacuum environment.

   Demands on the EC/LS system arise only from the need for crew egress through the airlock to set up the test and to retrieve the test coupons.

   There are no special storage or packaging requirements.

3. Data Requirements--The metal coupons are tested at the rate of one every other day. The fractured sample and an exposed sample are collected after the test for return to Earth.

   The parameters to be telemetered are test loads, times or cycles to fracture, and time in vacuum.

   The data will be recorded on graph paper and also in a log book. The log and graphs are returned to Earth.

4. Displays and Controls--One display will be an oscilloscope which is connected to the test machine through the laboratory walls. The scope checks the cycling action of the test samples while they are being tested. Another display is a temperature record of the coupon temperature history.

5. Vehicle Performance--No special vehicle performance is required.

A-10.6 GROUND-SUPPORT REQUIREMENTS

Approximately 100 coupon tests will be conducted in the Earth laboratories.

Section A-11

IONIZING - RADIATION MEASUREMENTS

(Data Bank Experiment No. IA-11)

A-11.1 PURPOSE

The purpose of this investigation is to measure the ionization radiation, to provide a time history of the radiation flux, and to identify the particle types and their energies, both inside and outside the spacecraft, from all sources of radiation (solar, galactic, cosmic, geomagnetically trapped, and man-made).

A-11.2 TASK DESCRIPTION

The observations to be made will consist of the measurement of the flux of high-, medium-, and low-energy alpha particles, protons, electrons, neutrons, and gamma rays immediately outside the spacecraft. Equivalent measurements would be made inside the spacecraft, and the two measurements would be correlated.

Crew functions will be as follows:

1. Daily for the first 30 days in orbit--Ionizing radiation measurements will be made at a frequency of ten 2-min. periods every orbit for both inside and outside sensors. These readings will be planned so that the entire orbital path is sampled in five orbits with overlap.
2. Remainder of laboratory life for internal sensors--The sampling frequency will be reduced to one 2-min. period per orbit or as required to ensure crew safety if regions of unusually high radiation are identified.
3. Periods of abnormally high radiation--It is assumed that on the average of once per month, a period of high radiation will require that 30 min. of continuous data will be taken in a leg of the orbit for 6 to 10 consecutive orbits and will require the use of outside sensing (SRT).

A-11.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skills:

Number	Name	Hours/Day
8	Photo/technician cartographer	1

A-11.4 EQUIPMENT REQUIREMENTS

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Telescope	1,500	120
	Pointing system gimbals	1,500	15
	Film and plates	100	1.5
4	Scintillation counter	8	0.8
4	Proportional counter	8	0.8
4	Sandwich spectrometer	4	0.8
90	Dosimeter (emulsion)	neg	neg
12	Dosimeter (electrometer)	neg	neg
12	Dosimeter (counter)	neg	neg
2	Geiger counter	7	0.2

A-11.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The mounting of the internal equipment would be limited to the fastening of four packages to the inside of the spacecraft radiation shield. Each package would contain a scintillation counter, a proportional counter, a sandwich spectrometer, and two power supplies.

   These packages will be mounted at 0°, 90°, 180°, and 270° about the laboratory circumference so that they are in the plane of the SRT. One of the four positions will be displaced slightly from the base of the boom supporting the SRT.

   Other equipment will be portable units or worn by the crewmen.

   The external ionizing radiation measurements will be accomplished with the space radiation telescope. The boom will be used to mount the SRT.

2. Environmental Requirements--Refrigeration and radiation shielding are required for the storage of emulsions. A volume of 0.1 cu ft should be adequate. Emulsion dosimeters will be refrigerated and shielded during shipment. Film processing chemicals will be shipped dry.

   A small, wet, photo-processing kit must be available on board the laboratory for processing of the small emulsions. Emulsions quantities will have to be sufficient for a 3-month period. A total of 90 emulsions will have to be stored for a 6-man crew.

3. Data Requirements--Developed emulsion dosimeter films will be returned to Earth.

   The following requirements exist for telemetry data:

   A. Sensors

      (1) 5 sensors: 3 analog outputs each.
      (2) Vehicle position and attitude: 6 analog outputs.
      (3) Boom and sensor position and orientation: 6 analog outputs.

   B. Sampling rate: One complete reading (189 bits) every 30 sec.

   C. Sampling period

      (1) First 30 days: ten 2-min. periods (equally spaced) per orbit,
      (2) Remainder of mission: one 2-min. period per orbit.
      (3) During storms (approximately 1/mo.): one 30-min. period per orbit, 6 to 10 orbits.

   D. Accuracy: 1%.

   E. Data

      (1) First 30 days: 114,000 bits/day.
      (2) Remainder of mission: 11,4000 bits/day.
      (3) During storms: 68,000 to 114,000 bits/day.

Normally, no on-board processing of telemetered data is required other than digitizing radiation level readings. During periods of abnormally high radiation intensity, the output of the SRT should be displayed on board.

4. Displays and Controls--The output from all sensors contained in the SRT will be displayed on the experiment console. This will be required during periods of abnormally high radiation intensity.

   Computer-controlled output include the following:

   A. Boom position (with manual override).

   B. Attitude of sensor on boom.

5. Vehicle Performance--No demands will be placed on spacecraft altitude control during the experiment.

A-11.6 GROUND-SUPPORT REQUIREMENTS

The ground support will act as a decision-making unit in case of high radiation orbits or unreasonably fogged negatives. Ground support will determine whether an emergency situation exists. It will also help in the location and the removal of objects which might have become activated after prolonged exposure to radiation.

Section A-12
EVALUATION OF BEHAVIORAL RESPONSES IN THE ORBITAL ENVIRONMENT, PART I
(Standard Behavioral Measurements)
(Data Bank Experiment No. IIIA-5)

A-12.1 PURPOSE

The objectives of this series of behavioral measurements is (1) to assist in the detection and diagnosis of any decrements in fitness or performance of the crew members and (2) to study the effects of the oribital environment on performance in a variety of relatively elementary tasks.

A-12.2 TASK DESCRIPTION

The crew members will participate as subjects in a series of standard behavioral measurements to evaluate crew performance as it relates to length of stay in the orbital environment.

The procedure for each measurement will consist of the following general format:

1. The subject is seated at the biomedical-behavioral experiment console. The subject positions the rotary selector switches to identify himself and the particular task to be evaluated.
2. The subject then sets up the particular test by inserting a film cartridge, adjusting the behavioral measurement chair, attaching a hood to the CRT display or whatever is required to adapt the console to the particular testing procedure. He then activates the run by pushing the Ready button, rotating the chair, donning ear-phones, and so forth as required.
3. The subject then responds to whatever stimulus is presented to him and the results are recorded automatically, stored, and later transmitted to Earth.

A-12.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: Total crew
2. Skills:

Number	Hours/day
All crewmen	0.6 hours/test/man

A-12.4 EQUIPMENT REQUIREMENTS

All equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Behavioral measurement subsystem	110	20
1	Behavioral measurement chair	27.5	6.6

A-12.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The behavioral measurement subsystem is part of the biomedical and behavioral test station. It includes those controls and displays that are primarily devoted to behavioral measurement, along with animation equipment and connections to the data management system. The estimates below do not include any part of the data management system.

   The chair is used to support and orient the subject for each measurement. The arms of the chair contain controls for selecting and initiating stimuli.

   The biomedical-behavioral console and behavioral measurement chair have been provided on the MORL to permit measurement of the biomedical and behavioral condition of the crew under controlled conditions.

   The work station is designed to permit concurrent measurement of behavioral and biomedical parameters, if desired. However, it is recommended that key behavioral tests and other items, such as centrifuge runs and exercise tests, be scheduled independently. The behavioral measurement system chair permits the subject to perceive body motion; it also serves as a biomedical couch, eliminating the need for a permanent couch.

   The left side of the console contains the biomedical monitoring and control capability. Included are status panels for biomedical parameters of each crew member, preamplifiers and amplifiers, an eight-channel CRT for visual analysis of waveforms, and other management controls. The control of the on-board centrifuge and display of subject status is included here. The CRT will double as a television monitor link for extravehicular crew operations and for visual monitoring of subjects during centrifuge runs. Extensive voice-communication capability, including two EVSTC channels, is provided for the biomedical monitor.

Insert-display and data management are located in the center of the console to permit operation of the data-handling from either operator seat. A patch panel is provided for data handling flexibility.

The area of the console to the right consists of the control and display interface provided for the behavioral measurement system. The measurement capability is designed around a retrograde and re-entry simulator, which is provided to maintain crew skills for operational re-entry. This capability, properly expanded to include electronic measurement of performance, provides the flexibility to measure key operational skills. Additional controls and displays represent an implementation of the spectrum of behavioral measure ments.

2. Environmental Requiements--There are no special environmental requirements.
3. Data Requirements--The results of each test run will be recorded automatically, stored, and later transmitted to Earth for analysis.
4. Displays and Control--See 2. (Equipment Installation Requirements), above.
5. Vehicle Performance--None.

A-12.6 GROUND-SUPPORT REQUIREMENTS

No special ground support is required.

Section A-13

EVALUATION OF BEHAVIORAL RESPONSES IN THE ORBITAL ENVIRONMENT, PART II

(Journal Recording) (Data Bank Experiment No. IIIA-6)

A-13.1 PURPOSE

This experiment will be to measure the crew's behavioral response to the orbital mission. Data will be gathered to assist in evaluating and predicting man's overall effectiveness in space.

A-13.2 TASK DESCRIPTION

Each crew member will tape record his daily activities. The crew will be asked to record certain standard topics and also to record occurrences and opinions as they occur. Members of the crew will be encouraged to speak frankly and only designated ground personnel, of whom each crew member approves, will be authorized to play the tapes and to evaluate the responses.

A-13.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: Total crew
2. Skills:

Number	Name	Hours/Day
	All crewmen will participate individually	0.25

A-13.4 EQUIPMENT REQUIREMENTS

The equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Voice Tape Recorder	5.0	0.05

A-13.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--A voice tape recorder should be located in a semi-enclosed, sound-shielded area to provide privacy during the recording session.

2. Environmental Requirements--There are no special environmental requirements.

3. Data Requirements--Voice tape recordings will be transmitted to Earth in a scrambled form within a week of each recording.

4. Displays and Controls--No displays and controls will be required on the experiment console.

5. Vehicle Performance--No special vehicle performance will be required.

A-13.6 GROUND-SUPPORT REQUIREMENTS

Behavioral specialists stationed on the ground will evaluate the recordings and make recommendations about their continued use.

Section A-14

RETENTION OF SKILLS LEARNED IN THE ORBITAL ENVIRONMENT (Data Bank Experiment No. IIIA-8)

A-14.1 PURPOSE

The objective of this experiment is to determine the degree to which a motor skill learned under the conditions of weightlessness would be retained in normal Earth gravity. The knowledge gained should provide insight into the basic mechanisms of adjustment for psychomotor functions under conditions of sensorimotor disarrangement. Two general types of measurement, tracking and dexterity, could be used.

A-14.2 TASK DESCRIPTION

All subjects will be tested with both the tracking and dexterity measure before they enter the laboratory; within a few days after returning to Earth; and again 3 months later. However, while on board the laboratory, only half of the subjects will practice the tracking task and will not be exposed to the dexterity task, and vice versa. Records of performance will be maintained.

A-14.3 CREW TIME AND SKILL REQUIREMENTS

Crew time and skill requirements are as follows:

1. Number of men required: six
2. Skill:

Number	Name	Hours/Day 1	Hours/Day 2
21 to 26	Subject	3.0	3.0
27	Observer	3.0	3.0

A-14.4 EQUIPMENT REQUIREMENTS

The equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Dexterity apparatus	1.0	0.25

A-14.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The tracking apparatus will consist of two handles connected electrically to a pointer control mechanism, which will be represented, along with a target, on a CRT. The target will be programmed to follow a path that appears random to the subject. Provisions will be made for recording a score, such as integrated error or time on target. The CRT will be the same as that planned for other purposes at the biomedical and behavioral test station, and the necessary programming is well within the capability of the data management system.

   The dexterity apparatus consists of two containers and some small, odd-shaped pegs. The subject would transfer the pegs from one set of containers to the other. Electrical contacts associated with the containers will sense the presence or absence of pegs and will control the starting and stopping of an interval timer.

2. Environmental Requirements--There are no special environmental requirements.

3. Data Requirements--Time or error data will be recorded for each session.

4. Vehicle Performance--No special vehicles performances is required.

A-14.6 GROUND-SUPPORT REQUIREMENTS

Ground testing of subjects is required prior to and after flight. No ground support is required during flight.

Section A-15

CREW PERFORMANCE IN ORBITAL AND RE-ENTRY OPERATIONS

(Data Bank Experiment No. IIIA-7)

A-15.1 PURPOSE

The purpose of this experiment is to evaluate the maintenance of crew performance in certain critical tasks as a function of stay time in orbit. The results will assist in the detection and diagnosis of any decrements in performances.

A-15.2 TASK DESCRIPTION

The following evaluations of the maintenance of crew performance will be performed.

1. Simulated Re-entry Performance--About once per month, each crew member will perform a simulated return to Earth using simulation apparatus which is associated with the biomedical and behavioral test station. The crew will activate simulated controls and observe simulated displays associated with the logistics vehicle. Procedures will be programmed to simulate the variation within the expected range of operating modes and missions (including certain equipment malfunction and other contingencies). The subjects will follow routine and abnormal procedure from beginning of checkout to landing. Time will be compressed, however, to de-emphasize those parts of the mission where crew actions are relatively unimportant or repetitive. Error scores will be recorded, stored, and displayed to the subject at the end of the session. Later, these data will be transferred to Earth.

2. Mass Handling--When using airlocks hatches for routine operation, crew members will note the force of opening and closing the airlock door. Readings will be recorded by each crewman on a paper report form. The subject will also indicate whether he is in shirt sleeves, pressurized space suit, or unpressurized space suit.

3. Donning Spacesuit--When donning his spacesuit for normal extra-vehicular operations, each crew member will activate a time device when he begins and will note the elapsed time when the suiting-up operation is completed. The elapsed time, amount of aid received, and any difficulties encountered will be recorded on a paper report

form for later transmission to Earth monitors. If, for a month, a crew member has no routine occasion to don his spacesuit, he will be scheduled for a practice session to ensure his retaining the skills needed for rapid donning.

4. Voice Communication--Routine voice communications from the laboratory will be evaluated by operational and beomedical monitors. Each monitor will, at intervals, complete a rating form covering such factors as intelligibility, logicality, and normality of each crew member who has been engaged in voice communication.

5. Television Interview--Every 10 days, each laboratory crew member will be interviewed privately by a ground observer. If feasible, the crew member will be televised so that the Earth observer can respond not only to his words but also to his facial expressions and general appearance.

6. Performance Ratings--The station commander and the flight surgeon will make weekly ratings of the performance of each crew member--not with a view to influencing crew performance, as such, but rather, as an additional aid in detecting decrement, should it occur. These ratings will be transmitted to the Earth monitor by a secure communication link. The time for this activity should be only about 0.5 hour.

7. Operational Re-Entry Performance--Each time a logistics vehicle is returned to Earth, crew performance will be measured to the maximum extent possible. Basically, the measurement to be recorded will include tracking error scores, number of procedural errors of omission and commission, and ratings of performance by ground monitors. These measurements will be correlated with biomedical measurements such as heart rate, blood pressure, respiration rate, body temperature, and oxygen consumption.

A-15.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: Total crew
2. Skills:

Number	Name	Hours/Day
	All crewmen will participate individually	1.25/man/test/30 days

A-15.4 EQUIPMENT REQUIREMENTS

The equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Re-entry simulator	35	0.33
1	Rendezvous and docking simulator	20	0.33
1	Tracking simulator	20	0.33

A-15.5 OPERATIONAL REQUIREMENTS

1. Equipment Installation Requirements--An impact sensor is required on each airlock door. A direct readout of maximum impact force must be supplied.

   A television and audio communication channel with the Earth is required. This apparatus will be integrated into the biomedical and behavioral test station. It will consist of controls and displays simulating those of primary importance in the ferry vehicle, along with means for mechanizing them and connecting them to the data management system.

2. Environmental Requirements--There are no special environmental requirements.

3. Data Requirements--Error scores on the simulation tests will be recorded, stored, and later transmitted to Earth by the data management system. These data will also be made available for display to each subject at the conclusion of the session.

   Observations such as force readings and time to don spacesuits, will be recorded on paper forms by the subjects and later transmitted to Earth.

4. Displays and Controls--(See above)

5. Vehicle Performance--No special vehicle performance is required.

A-15.6 GROUND-SUPPORT REQUIREMENTS

Ground monitors will be required for evaluating the results of each test and for recommending corrective procedures.

Section A-16

VENTILATION OF RESPIRED GASES IN MANNED SPACE ENCLOSURES

(Data Bank Experiment No. IIID-17)

A-16.1 PURPOSE

The objective of this experiment is to determine the minimum atmospheric requirements for human and animal support in sealed and artificially engineered environments under the influence of the orbital environment. The results will be used to supplement metabolic data obtained from related experiments on biological energy management and to establish power requirements for both normal and emergency conditions.

A-16.2 TASK DESCRIPTION

Continuous monitoring of certain vehicular atmosphere components would be accomplished by gas chromotographic procedures. These data would support the periodic analyses of the atmosphere for individual known and unknown components by other methods, for example, ultraviolet and infrared techniques, spectrographic methods, chemical analyses, and individual sensors for components such as oxygen, water vapor, carbon dioxide, and carbon monoxide.

The validity of gas chromatographic analysis depends on the frequent calibration of the instrument with a known mixture of compounds similar to the unknown compounds to be identified and measured. Calibration will be done by a known synthetic gas mixture whose components the instrument can monitor. It will be necessary to perform a calibration run before every determination of unknowns.

A-16.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skill:

Number	Name	Hours/Day 1	Hours/Day 2
12	Electromechanical technician	0.5	0.5

A-16.4 EQUIPMENT REQUIREMENTS

The equipment requirements are as follows.

Quantity	Item	Weight (lb)	Volume (cu ft)
2	Gas chromatograph	24.0	1.0
1	Calibration gas mixtures	0.5	neg
2	Carrier gas supply	4.0	0.1
2	Storm allar for calibration gas mixture	7.0	neg

A-16.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The gas chromatograph instrument is packaged in three separate modules.
   - A. Helium Reservoir--This reservoir is for storage of the carrier gas and a high-pressure regulator. It could be mounted anywhere inside or outside the space vehicle.
   - B. Analyzer--The sampling values would be located to permit the sampling of atmosphere entering and leaving the atmospheric control systems. The detectors and associated electronics would be flight mounted on a suitable work bench.
   - C. Readout Mechanisms--These mechanisms can be located with the detectors and other electronic equipment.
2. Environmental Requirements--There are no special environmental requirements.
3. Data Requirements.
   - A. Parameters--The following parameters will be involved in this experiment:
     - (1) Oxygen.
     - (2) Nitrogen.
     - (3) Carbon Dioxide.
     - (4) Water.

(5) Hydrogen.
(6) Methane.
(7) Ammonia.
(8) Carbon Monoxide.
(9) Ozone.
(10) Nitrogen oxides.

B. Type of Signal--The following types of signals are required in this experiment:

(1) Analog.
(2) Digital.
(3) Discrete (output voltage is useful for telemetry, especially in the detection of unknown compounds).

C. Duration and Repetition Rate of Each Parameter--The time required for complete analyses of calibration gases and entrance and exit air from the atmospheric control systems will be about 30 min and will represent the repetitive role of each parameter. These analyses will be repeated every 30 min.

4. Vehicle Performance--No special vehicle performance is required.

A-16.6 GROUND-SUPPORT REQUIREMENTS

No special ground support is needed, unless aid is required for the identification of an unknown contaminant in the vehicle atmosphere.

Section A-17
EVALUATION OF LIFE SUPPORT SYSTEM TO DETECT MICROBIOLOGICAL AND CHEMICAL CONTAMINANTS
(Data Bank Experiment Number IIID-16)

A-17.1 PURPOSE

The purpose of this experiment is to monitor spacecraft life-support systems for the presence of microbiological contaminants. The results would contribute to the improved design of life support and environmental control systems.

A-17.2 TASK DESCRIPTION

The water and purified air supplies will be sampled continuously for bacterial contamination. Sampling systems will include by-pass lines with micropore filters in the outlet streams through which metered volumes will be passed and contamination will be collected on the filters. These filters will be replaced daily by sterile filters. The contaminated filters will be examined in the following sequential steps:

1. Micropore filter is placed on a sterile plastic nutrient Agar plate.
2. Filter is covered and incubated at 37°C for 24 hours.
3. Filter is examined for bacterial colonies and foreign particles by high-magnification (100-200X) microscopic analysis.
4. Number of bacteria colonies and foreign particles is observed per day per volume of water or air recorded. Observations are standardized to constant daily volumes.
5. Contaminated filters and plates are disposed of through the food-waste handling system. Covers are sterilized for reuse.

A-17.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: one
2. Skill:

Number	Name	Hours/Day 1	Hours/Day 2
1	Biotechnician	1.2	1.2

A-17.4 EQUIPMENT REQUIREMENTS

The equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
440	Micropore filters	2.19	neg
588	Plastic plates	0.66	neg
147	Nutrient gel tubes	2.35	0.2
1	Sterile water	7.40	0.1
1	Incubator	10.5	1.0
120	Aluminum covers	0.45	neg

A-17.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The incubator, microscope, and steam sterilizer will be enclosed in a hood equipped with a suction fan and ducted to the air-purification system. The hood will be 3 x 2 x 3 ft in size. It will also be equipped with an ultraviolet light source for sterilizing spilled bacterial preparations. The space under the working area will be used to store experimental supplies. Steam for sterilization is supplied by a self-contained generator.

   The accessories, including filters, Agar plates, nutrient Agar tubes, and sterile water, will be packaged in sterile plastic containers until used. The used materials will be discarded through the food-waste disposal system. Many of these items can be made of materials disposable in the waste management system.

2. Environmental Requirements--The operating temperatures of the incubator and sterilizer will be $37^{\circ}C \pm 0.5^{\circ}C$ and $200^{\circ}C$, respectively. The hood fan will prevent this equipment's heat loss from affecting the internal operational area of the laboratory. The experimental equipment heat output will be 7,600 btu per day.

3. Data Requirements--Each of the following will be measured and logged once daily throughout the life of the laboratory:

   A. Water supply bacterial count.
   B. Air supply bacterial count.
   C. Air supply foreign particle count.
   D. Waste disposal systems bacterial counts.
   E. Degree of surface contamination at predetermined sites.

4. Vehicle Performance--No special vehicle performance is required.

A-17.6 GROUND-SUPPORT REQUIREMENTS

No special ground support is required.

Section A-18

FORCE PRODUCING CAPABILITIES OF OPERATORS IN ZERO G

(Data Bank Experiment No. IIIA-4)

A-18.1 PURPOSE

The purpose of this experiment is to gather quantitative data regarding man's capability to perform various manual tasks in the orbital environment. In conjunction with these tests, oxygen consumption will also be evaluated.

A-18.2 TASK DESCRIPTIONS

Each crewman will periodically perform various manual tasks with a variety of tools and equipment in order to evaluate force-producing capabilities. The tasks will be accomplished in pressurized and unpressurized space suits and in shirt-sleeves. Both restrained and unrestrained conditions will be included.

The subjects will perform the tests according to the directions provided in a protocol sheet. Generally, this will involve donning appropriate clothing, setting up equipment and tools, performing tasks, and recording elapsed times, force readings, etc. The tests will include (1) arm strength (seated), (2) push and pull by hand (standing), (3) leg force (seated), (4) grip strength and endurance, (5) strength of hand turn, (6) elbow and shoulder strength, and (7) back and leg strength.

A-18.3 CREW TIME AND SKILL REQUIREMENTS

The crew time and skill requirements are as follows:

1. Number of men required: Total crew
2. Skills:

Number	Name	Hours/Day
	Crewmen will participate individually	0.5 hour/man/test/6 days

A-18.4 EQUIPMENT REQUIREMENTS

The equipment requirements are listed below.

Quantity	Item	Weight (lb)	Volume (cu ft)
1	Restraint and bracing device	3.0	1.0
1	Force testing unit	15.8	1.3
1	Dexterity testing unit	7.0	0.6
1	Tools and equipment	30.8	0.8

A-18.5 OPERATIONAL REQUIREMENTS

The operational requirements are as follows:

1. Equipment Installation Requirements--The primary testing unit is a multipurpose universal load shaft with equal applicability to determine isometric and isotonic force and work-producing capabilities. Quick-snap devices will be employed to change task and mode of operation.

   For space-suited operations, an electrocardiograph is required to constantly monitor the subject's pulse rate. Space suit thermal monitors will also be used during the tests.

2. Environmental Requirements--There are no special environmental requirements.

3. Data Requirements--Continuous pulse rate monitoring is required during each test session in order to determine oxygen uptake. Body temperature recordings are also required throughout the testing procedures. A miniaturized transmitter will be used to avoid umbilical problems.

   The quantitative measurements of force- and work-producing capabilities will be entered on paper formats, transcribed to tape, and transmitted to Earth as desired.

4. Displays and Controls--Mechanical readout devices will be employed with the mechanical force-loading components to minimize subsystem dependency.

5. Vehicle Performance--No special vehicle performance is required.

A-18.6 GROUND-SUPPORT REQUIREMENTS

Test data will be transmitted to the ground for analysis.